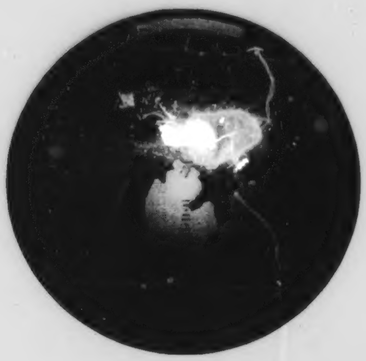
State of the Lakes Ecosystem Conference



Selection of Indicators for Great Lakes Basin Ecosystem Health

Version 4

Prepared by:

Paul Bertram
United States Environmental Protection Agency

Nancy Stadler-Salt
Environment Canada

March 2000

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Prepared by:

Paul Bertram
United States Environmental Protection Agency, GLNPO
77 West Jackson Blvd.,
Chicago, IL 60604
USA

Nancy Stadler-Salt
Environment Canada
867 Lakeshore Rd.,
Burlington, Ontario L7R 4A6
Canada

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Notice to Readers

*This is the fourth version of the SOLEC report **Selection of Indicators for Great Lakes Basin Ecosystem Health** released by the SOLEC steering committee. The four versions of this report represent a continuum of work on indicators for determining Great Lakes ecosystem health - continuing the development, refinement and acceptance of a suite of Great Lakes indicators.*

The concepts and ideas contained in this paper were first assembled for discussion at SOLEC 98 (October 21-23, 1998). The SOLEC deliberations were an important step in the process. Participants reviewed the SOLEC 98 document prior to SOLEC and provided comments, specific information and / or references during the breakout sessions, on the comment forms or directly to the authors. These comments were considered during the preparation of the revised post-conference SOLEC Indicator List (Version 3). Major changes included the deletion of a few indicators, additions of a few others, revisions to the indicator descriptors of all, summary of a criteria assessment and the inclusion of a section of the different ways the SOLEC indicators may be sorted and organized.

*In Version 4 of **Selection of Indicators for Great Lakes Basin Ecosystem Health**, a few indicators have been dropped, added or moved to another category, the short descriptions of each indicator have been modified and individual indicators have been refined.*

> The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins, and which the Parties can use to report status and trends every two years. This suite of indicators will also be used to assess the Parties progress toward achievement of the purpose and general objectives of the GLWQA.

SOLEC

Selection of Indicators For Great Lakes Ecosystem Health

1.0 Introduction

1.1 History of SOLEC

The State of the Lakes Ecosystem Conferences (SOLEC) are hosted by the U.S. Environmental Protection Agency and Environment Canada, every two years on behalf of the two countries in response to the Great Lakes Water Quality Agreement (GLWQA). Canada and the United States are known as the Parties to the GLWQA. SOLEC conferences are intended to focus on the condition of the Great Lakes ecosystem and the major factors impacting it, and to provide a forum for exchange of this information. These conferences are not intended to discuss the status of programs needed for its protection and restoration. Another goal of the conferences is to reach a large audience of people in all levels of the government, corporate, and not-for-profit sectors who make decisions that affect the Lakes.

The conferences are the focal point of a process of gathering information from a wide range of sources and engaging a variety of organizations in bringing it together. In the year following each conference the Governments have prepared a report on the state of the Lakes based in large part upon the conference process.

The first conference, held in 1994, addressed the entire system with particular emphasis on aquatic community health, human health, aquatic habitat, toxic contaminants and nutrients in the water, and the changing Great Lakes economy. The 1996 conference focused on the nearshore lands and waters of the system where biological productivity is greatest and humans have had maximum impact. Emphasis was placed on nearshore waters, coastal wetlands, land by the Lakes, the impact of changing land use, and information availability and management. For both conferences indicators were chosen and, based on expert opinions, subjective assessments were provided as to the conditions in terms of good, fair, poor, etc.

In planning for SOLEC 98 the organizers wanted to support further development of easily understood indicators which objectively represent the condition of the Great Lakes ecosystem components. These would be used every two years to inform the public and report progress in achieving the purpose of the GLWQA: *to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Ecosystem.* The SOLEC indicators would reflect conditions of the whole Great Lakes basin and its major components (a general system-wide overview), and they would draw upon and complement indicators used for more specific purposes such as Lakewide Management Plans (LaMPs) or Remedial Action Plans (RAPs) for Areas of Concern.

Beginning with SOLEC 2000 and continuing for at least the next decade, progressively more indicators will be reported at each conference until the entire suite is included. The indicators presented in this report comprise the SOLEC indicators list for SOLEC 2000. The list should be considered dynamic, and modifications and adjustments can be expected as the list evolves to reflect better understanding of Great Lakes ecosystem functioning and human interactions with and within the ecosystem.

2.0 Indicators

2.1 What is an Indicator?

The concept of indicators is quite familiar. They can be thought of as pieces of evidence, or clues, that tell us something about the condition of something of interest. For example, doctors use blood pressure and weight to gauge human health, and economists use interest rates and housing starts to assess the health of economies. Similarly, environmental indicators provide bits of information that are useful to us to assess our surroundings. Indicators, when tracked over time, provide information on trends in the condition of the surroundings.

> Indicators can be thought of as pieces of evidence that help us assess the condition of something of interest.

During the organization of a set of indicators for SOLEC, it became apparent very quickly that a number of related terms and concepts could be confusing. Some basic definitions are presented here to provide the context for the SOLEC indicators project.

Vision	A general description of the desired state of a lake, geographical area, etc., as expressed by a group of stakeholders.
Goal	A condition or state desired to be brought about through a course of action. Goals are usually qualitative statements that provide direction for plans and projects.
Objective	Specific descriptions of the state or condition that must be met in order to achieve goals and the vision.
Indicator	A parameter or value that reflects the condition of an environmental (or human health) component, usually with a significance that extends beyond the measurement or value itself. Indicators provide the means to assess progress toward an objective.
Data Point	A single measurement of an environmental feature. Data points may be combined to serve as an indicator.
Endpoint	Specific, attainable, quantitative target or reference values for an indicator that provides the context for assessing whether or not an objective is being met.

An indicator is more than a data point. It consists of both a value (which may be a direct environmental measurement or may be derived from measurements) and an endpoint or reference value. The indicator is intended to be used, alone or in combination with other indicators, to assess progress toward one or more objectives. For SOLEC purposes, the objectives may be expressed in the Great Lakes Water Quality Agreement, LaMPs, RAPs, Fish Community Objectives, or other generally accepted Great Lakes planning documents. In addition, to be widely used by decision-makers and others, indicators should be readily understood by a broad audience.

2.2 Types of Indicators

There are several classification schemes for indicators, which encompass everything from human actions (e.g., the number of participants in public hearings) to environmental measurements (e.g., the number of bald eagle fledglings per breeding pair). SOLEC has adopted the State—Pressure—Human Activities (Response) indicator model. This framework is considered one of the most widely accepted classification schemes for environmental indicators because of its simplicity and broad applicability. The SOLEC indicators can be classified according to the following types:

> **State (of the Environment):** These indicators address the state of the environment, the quality and quantity of natural resources, and the state of human and ecological health. They reflect the ultimate objective of environmental policy implementation. The indicators are chosen by considering biological, chemical and physical variables and ecological functions.
>
> **Pressure:** These indicators describe natural processes and human activities that impact, stress or pose a threat to environmental quality.
>
> **Human Activities (Response):** These indicators include individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment. They also include actions for the preservation and the conservation of the environment and natural resources. Examples of actions include education, regulation, market incentives, technology changes, etc.

These three indicator types are closely linked. For example, the *pressure* (or stressor) of a particular pollutant entering a system may cause a change of *state* of some species (i.e. population declines) which may, in turn, cause a *response* of (additional) restrictions on the discharge of the pollutant. The additional restrictions reduce the *pressure* which improves the *state*. Most SOLEC indicators will be of types State or Pressure, reflecting the focus of the Conference.

2.3 Scale

Indicators may be selected to reflect environmental conditions on a variety of scales in both space and time. From a satellite, one can obtain an image of the entire Great Lakes basin. From an airplane, one can view an entire lake or lake basin. From a canoe, one can view a single turtle. Indicators identified for SOLEC are intended to be generally applicable on a basin-wide or lake basin scale. Lake-by-lake differences may exist in endpoints or reference values for some indicators, but the indicators themselves should be relevant across lakes. Indicators of local conditions, as might be presented in Remedial Action Plans for Areas of Concern, are not the focus for SOLEC. In addition, the indicators identified for SOLEC should reflect changes in conditions in the short, medium, and long-term.

2.4 The Need for an Indicator List

One way to determine the status of the health of the Great Lakes ecosystem is to use indicators, which address a spectrum of conditions ranging from the health of humans and other living components of the system to the stressors and the activities that cause them. Ecosystem health indicators reflect ecosystem quality or trends in quality that are useful to managers and scientists. However, ecosystems are inherently complex so that any single indicator (or even suites of indicators) cannot be completely representative of all possible conditions.

The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins, and which the Parties can use to report status and trends every two years. This suite of indicators will also be used to assess the Parties progress toward achievement of the purpose and general objectives of the GLWQA.

The goal of this project is to assemble a basin-wide suite of scientifically valid indicators that will be most useful and understandable in determining and reporting the health of the Great Lakes ecosystem to the interested public.

The SOLEC process has assembled a set of indicators that reflects the state of major ecosystem components for the Great Lakes, including open and nearshore waters, coastal wetlands, nearshore terrestrial environments, human health, stewardship, and socio-economics/land use. The indicators nominated for the SOLEC list were extracted primarily from existing Great Lakes documents (see Appendix 7), (e.g., Lakewide Management Plans, Fish Community Goals and Objectives, and International Joint Commission (IJC) proposed indicators of desired outcomes).

2.5 Why Should There be Agreement on Indicators?

The demand for high quality, relevant data concerning the health of various components of the Great Lakes ecosystem has been escalating rapidly for the past decade or so. The U.S. and Canada have spent billions of dollars and uncounted hours attempting to reverse the effects of cultural eutrophication, toxic chemical pollution, over-fishing, habitat destruction, introduced species, etc. Environmental management agencies are being asked to demonstrate that past programs have been successful and that the success of future or continuing programs will be proportional to the resources expended (financial and personnel time). At the same time, in both countries, the amount of taxpayers dollars being devoted to Great Lakes environment issues is decreasing. The demand for high quality data, while operating with limited resources, is forcing environmental and natural resource agencies to be more selective and more efficient in the collection and analysis of data.

The most efficient data collection efforts will be those that are cost-effective and relevant to multiple users. An understanding by stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health through the use of indicators, and to measure progress toward ecosystem goals, would facilitate efficient monitoring and reporting programs. Common databases would provide easier access to relevant supporting data, and the relative strengths of the agencies could be utilized to improve the timeliness and quality of the data collection.

The International Joint Commission (IJC) has a responsibility to evaluate progress toward achieving the goals and objectives of the GLWQA. A set of indicators that is relevant to both the IJC and the Parties will prevent a dilution of monitoring effort for competing purposes, and will foster cooperation between the Parties and the IJC for the common good of the Great Lakes ecosystem. Data will be collected for pre-determined applications, and they will be available on a timely basis. This system of a core set of indicators will be flexible enough to expand to take into account new emerging issues.

Access by non-government organizations (NGOs) to environmental data should become easier, and the data should be more timely and more relevant to a wide variety of stakeholders. Results of government programs for environmental protection and restoration (or lack thereof) would be easier to identify.

Achieving consensus on a set of core indicators means that individual programs and jurisdictions may continue to maintain their own unique indicators. Individual user groups may need to retain certain indicators or other data requirements that are not shared by other groups. The SOLEC process will not attempt to impose a uniform set of indicators onto all user groups, nor will it discourage new indicator development work. However, the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts for a common broad scale set of indicators. An understanding by multiple stakeholders about what information is necessary and sufficient to characterize the health of the Great Lakes ecosystem should foster cost-efficient, standardized, and relevant monitoring programs.

...the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts...

3.0 The Process for Selecting SOLEC Indicators

3.1 Pre-SOLEC 98

In preparation for SOLEC 98, a SOLEC Indicators Group was established by the SOLEC Steering Committee and asked to identify a set of indicators that reflects the state of all major Great Lakes ecosystem components. The Indicators Group consisted of volunteers from government, industry, academics, plus contracted writers/coordinators, each an expert in some aspect of the Great Lakes ecosystem. Because of the high degree of interest in this project, representatives from the LaMP work groups, IJC, and other government agencies participated as their time permitted.

The enormous task of finding indicators applicable to the Great Lakes basin ecosystem was originally divided into seven Core Groups, each lead by experts in the respective fields:

Open waters;
Nearshore waters;
Coastal wetlands;
Nearshore terrestrial (land by the Lakes);
Human health;
Socio-economics/Land use; and
Stewardship

Each of the seven groups proceeded to select a set of indicators for its domain that would be proposed as part of the SOLEC list. The Indicators Group coordinated the work, setting out guidelines for the process (outlined below), arranging conference calls, etc. The groups worked largely independently, but each group followed a process somewhat similar to that listed below. Alternative and/or additional steps in the process followed by some groups are presented in the specific group sections of this report.

The following is a list of activities that each group undertook to select a list of proposed SOLEC Indicators:

1. **Assembled a group of experts.** Each group identified and invited additional experts to assist in the selection or review of the proposed indicators. Efforts were made to include both Canadian and U.S. representatives on the expert panels, but representation from every agency was not attempted.

2. **Reviewed and extracted proposed indicators from Great Lakes documents.** An initial list of 55 documents was identified early in the process, and this list was the starting point for each group. The documents included reports from previous SOLEC conferences, the LaMP work groups, the IJC, the Great Lakes Fishery Commission, the Great Lakes Water Quality Agreement, and others. Each group was also encouraged to find and use other sources for Great Lakes indicators. See Appendix 7 for a list of documents used by the Core Groups.

3. **Identified potential indicators from non-Great Lakes documents.** Some groups found that few indicators had been proposed for the Great Lakes for their domain or that other, non-Great Lakes sources provided relevant indicators or approaches. As time permitted or need required, these additional sources were consulted, and indicators not previously proposed for the Great Lakes were identified. Appendix 7 also includes these documents.

4. **Entered information about potential indicators into a database.** A relational database was created specifically to assist the Indicator Group assemble, maintain and sort through the potential indicators for the SOLEC list. Each indicator extracted from (or mined out of) the documents was entered into the electronic database. See Section 3.7 and Appendix 5 for a detailed description of the database, the information retained about each indicator, and its potential usefulness to other user groups. In addition, see Appendix 2 for a full listing of all indicators entered into the database.

5. **Screened the indicators using a broad set of SOLEC criteria.** There were three general criteria that had to be met for an indicator to be put forward as a candidate for a SOLEC indicator:

Necessary - Do we really need to monitor a particular indicator? We want to gather information that is necessary to assess ecosystem health.

Sufficient - Will the suite of indicators give us enough information to assess the health of the Great Lakes ecosystem? We don't want to make an overall assessment of ecosystem health from too few indicators.

Feasible - Can the information reasonably be gathered, considering budgetary and monitoring constraints? The ideal situation would be if a monitoring program is already in place to gather the needed information.

6. Selected a subset (short list) of indicators from the database to be proposed for the SOLEC Indicators List based on expert opinion. The groups varied considerably in their approach to this critical task. For some groups (e.g., coastal wetlands, nearshore terrestrial), an active expert panel reviewed the entire list of indicators related to their domain, provided advice about the selection of an appropriate subset, and/or were involved in the combining or modification of indicators to create a subset more suitable for SOLEC needs. For other groups, the group leaders provided most of the energy for identifying the subset, and the expert panel was consulted during the process or provided review comments. Consultation with the expert panels has continued beyond SOLEC 98.

7. Screened the short list of indicators with a comprehensive set of SOLEC criteria. A set of selection criteria were adapted from an EPA document, *Process for Selecting Environmental Indicators and Supporting Data*, and modified slightly to better fit this project. These 21 criteria fall under seven categories: validity, understandibility, interpretability, information richness, data availability, timeliness, and cost considerations. These criteria will continue to be the basis for the review, selection and refinement of the indicators proposed for the SOLEC list. Reviewers of the SOLEC list have been encouraged to refer to these criteria when suggesting improvements, additions or deletions from the list. These criteria can be found in Appendix 4.

8. Sent the short list (Version 1) out for review. During the review process of the selected indicators, stakeholders were invited to provide advice on what indicators would be useful and interesting - June, 1998

9. Comments from review considered and revisions made. A draft report and SOLEC Indicator List (Version 2) were prepared for discussions at SOLEC 98 in October 1998.

10. Identify ecosystem components for which additional indicator development is needed. This step has been and will continue to be considered throughout the process.

3.2 SOLEC 98

Many discussions about the Indicators List were held at SOLEC 98. The conference workshops looked at the individual core group suites of indicators as well as the total suite of indicators (basin-wide overview). Many comments, concerns, suggestions and plain old-fashioned good advice were garnered from these sessions. A more detailed description of the SOLEC 98 indicator workshops can be found in the "SOLEC 98 Conference Proceedings" document (available on-line at www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/).

3.3 SOLEC Indicators List - Version 3

The majority of the comments from the SOLEC 98 workshops were thoroughly discussed at a meeting of the core group leaders in January 1999. As a result of these discussions a few indicators were deleted or combined with others, a few new indicators were added and the remainder were revised as appropriate.

After the revisions were made, each indicator was subjected to a clarification and consistency check. The purpose of this was to ensure that the indicators are clear and understandable and that they all follow a similar format. This process resulted in a much better indicator descriptor (see Appendix 1) and also helped to identify gaps in information as well as identifying future research needs.

For each indicator in Version 3 of the *Selection of Indicators for Great Lakes Basin Ecosystem Health*, a third party assessment against the SOLEC criteria was also undertaken. The results of this assessment can be found in Appendix 4 of Version 3.

In addition, and as a result of comments heard at SOLEC 98, the indicators have been categorized in several ways, in order to meet the needs of SOLEC and other interested stakeholders. The indicators can now be sorted and organized for many different means. For example, you may be interested in seeing a list of all the SOLEC indicators that relate to the GLWQA Annex 12, Persistent Toxic Substances. These can then be sub-categorized by state, pressure, and human activity. For more details on many indicator sorting possibilities please see Appendix 3.

Version 3 of the *Selection of Indicators for Great Lakes Ecosystem Health* was distributed for broad review to a wide variety of stakeholders. It was reviewed from both a technical standpoint and a policy standpoint in order to generate an understanding of the project, as well as getting buy-in and commitment. Comments received from the review were used to generate Version 4 of the indicator list and report. The majority of these comments, along with responses formulated by the core groups, can be found in Appendix 9.

3.4 State of the Great Lakes 1999

The State of the Great Lakes reports are produced in an effort to tie together all the information discussed at the SOLEC conferences. These reports are released about a year after the respective conference. The 1999 State of the Great Lakes report was released in November 1999 and not only discussed the indicator process but also reported on 19 of the 80 indicators.

3.5 SOLEC Indicators List - Version 4

The major changes to the Indicator List are:

- Indicator 72, Fish Entrainment, was removed from the list. This indicator has been incorporated into indicator 6, Aquatic Habitat.

- Indicator 9001, Atmospheric Visibility: Prevention of Significant Deterioration, was removed from the list. This indicator was removed as it was not widely viewed as "*necessary*" in order to determine the health of the Great Lakes basin ecosystem.
- Indicator 9002, Exotic Species, was added. This indicator has been added as a placeholder at this time to fill a gap in the previous indicator list. A more fleshed out indicator is anticipated to be presented at SOLEC 2000.
- A list of contaminants of common concern to most Great Lakes regions and ecosystem components has been determined. These were derived from the priority or critical contaminant lists from GLWQA, IADN, BNS, and the LaMPs. The list is intended to reflect contaminants of a basin-wide concern.
- The "Purpose" statements for each indicator have been modified to more correctly reflect the intent of each indicator.
- Some of the indicators have been revised based on comments received from the last review - the most significantly revised indicators are included in the Nearshore and Open Waters group.
- The spreadsheet in Appendix 3 has been modified to better reflect the relevant links to other works and environmental issues.
- Some indicators have re-categorized within different SOLEC core groups, and some have changed indicator types (pressure, state or human activity)

3.6 Where Do We Go From Here?

We've only just begun the journey! It is anticipated that there may be continual adjustments, refinements and revisions either to individual indicators or to the list as a whole. The SOLEC Indicators List is a living list. New emerging issues must be considered as they arise and potentially the list expanded to include indicators of the issues.

The SOLEC Indicators List currently contains 79 indicators that together can be used to assess the health of the major ecosystem components of the Great Lakes basin ecosystem. However, for many of the indicators more research or information is needed before the indicator can be used and data collected for it. Buy-in and commitment to the process by the various Great Lakes agencies and stakeholders is also necessary. This includes a commitment to monitoring and data collection.

Data gathering efforts for some of the indicators are underway in order to assess and report on as many indicators as is possible at SOLEC 2000 and in future State of the Great Lakes reports. However, the 79 indicators are not organized to answer the questions most frequently asked by the public: How is the water - is it safe to drink? How is the air - is it safe to breathe? How are the fish - are they safe to eat? Therefore, for SOLEC 2000, the 79 indicators may be grouped and reported on within environmental compartments and issues, such as: air, water, land, persistent toxic chemicals, exotic species...

3.7 The SOLEC Indicators Database

To assist the Indicator Group collect and sort indicators from existing documents, a database was designed to retain two main types of information about each indicator: 1) information useful for sorting the indicators according to various user perspectives, and 2) a detailed description of each indicator. Because the database contains information about indicators, but does not contain any of the environmental measurements, the information is more appropriately described as meta-data.

Within the database, each indicator under consideration for the SOLEC list was designated "Under Consideration." After a decision about an indicator had been reached regarding its inclusion on the SOLEC list, its status was changed to "Selected," "Not Selected," or "Concept Retained." See Appendix 5 for more details about these designations.

The "sorting" part of the database contains fields whose elements are selected by pull down pick lists. For example, information is stored concerning the type of indicator (i.e. state, pressure or human activity) and applicable SOLEC group (i.e. open waters, nearshore waters, coastal wetlands...). Nearly all of the indicators entered into the database are associated with some or all of these fields.

The "description" part of the database contains text fields that provide details about the indicator itself. This information is provided, to the best extent possible, for each of the indicators that make up the SOLEC list. For many of the other indicators in the database, this information was either not available or remains within the source documents but was not transferred to the database. The text fields include: indicator purpose, ecosystem objective, indicator features, desired endpoint (or range, outcome or other reference value), indicator limitations, indicator interpretation, additional comments, and a list of other groupings for which the indicator is relevant.

Originally conceived as an organizing and sorting tool for the SOLEC Indicator Group, the database may have value to other user groups. Therefore, an explanation and/or rationale for each of the database fields is provided in Appendix 5. Since SOLEC 98, work has proceeded on the database to make it more useable to a broader audience as well as making it more user friendly. An interactive on-line version is expected to be available by fall 2000. Please check the SOLEC websites frequently.

4.0 Indicator Core Groups

Please note: the following sub-sections have been substantially edited for brevity. If you require further details on the process of each core group then please refer to the October 1998 draft of "Selection of Indicators for Great Lakes Basin Ecosystem Health," or contact one of the Core Group leaders.

4.1 Nearshore and Open Waters

Definition of Nearshore and Open Waters
For the purposes of SOLEC 98 the nearshore and open waters are defined as in the SOLEC 96 background paper "Nearshore Waters of the Great Lakes." The definitions may be paraphrased as follows:

The nearshore waters largely occupy a band of varying width around the perimeter of each lake between the land and deeper offshore waters of the lake. The band begins at the shoreline or the lakeward edge of the coastal wetlands and extends offshore to the deepest lake-bed depth contour at which the thermocline typically intersects with the lake bed in late summer or early fall. Also included as nearshore waters are the Great Lakes connecting channels and the reaches of tributaries that are subject to seiche activity. Offshore Waters, as the name implies, are all of the waters beyond the lakeward edge of the nearshore waters.

Scale
An attempt was made to develop individual indicators that could be used to provide basin-wide status and trend information for the aquatic resources and habitats of the Great Lakes. Whenever possible, reference values have been provided specific to each lake to reflect significant natural differences between lakes, whether those differences occurred historically or are found currently.

4.1.1 The Indicator Selection Process

The Open Waters (OW) and Nearshore Waters (NSW) Core Groups proceeded independently during the initial phases. However, many of the indicators in one group were duplicated by the other. The two groups and their lists were consolidated for reconsideration and elimination of duplicative entries.

The groups' philosophical approach was to present the minimum number of indicators needed to address the important environmental issues of concern. The indicators needed to have solid scientific underpinnings yet be presented in terms that could be easily understood by a non-technical audience.

> ...present the minimum number of indicators needed to address the important environmental issues...

Currently, the Nearshore and Open Waters indicator list contains 20 indicators (of which one indicator, 8142, is also grouped with the Nearshore Terrestrial group).

4.1.2 Open and Nearshore Waters Indicators

Note: The numbers preceding the indicator name (here and in all the following Core Group sections) are a means of identifying the indicator in the database.

STATE
Fish Habitat (Indicator #6)

This indicator will assess the quality and amount of aquatic habitat in the Great Lakes ecosystem, and it will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

Salmon and Trout (Indicator #8)

This indicator will show trends in populations of introduced trout and salmon populations, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

Walleye and *Hexagenia* (Indicator #9)

This indicator will show the status and trends in walleye and *Hexagenia* populations, and it will be used to infer the basic structure of warm-coolwater predator and prey communities; the health of percid populations; and the health of the Great Lakes ecosystem.

Preyfish Populations (Indicator #17)

This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

Native Unionid Mussels (Indicator #68)

This indicator will assess the population status of native Unionid populations, and it will be used to infer the impact of the invading Dreissenid mussel on the Unionid mussel.

Lake Trout and Scud (*Diporeia hoyi*) (Indicator #93)

This indicator will show the status and trends in lake trout and scud populations, and it will be used to infer the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Nearshore Fish (Indicator #101)

This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in nearshore fish, and it will be used to infer areas of degraded habitat within the Great Lakes.

Benthos Diversity and Abundance (Indicator #104)

This indicator will assess species diversity and abundance in the aquatic oligochaete community, and it will be used to infer the relative health of the benthic community.

Phytoplankton Populations (Indicator #109)

This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes, and it will be used to infer the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Zooplankton Populations (Indicator #116)

This indicator will assess characteristics of the zooplankton community, and it will be used to infer over time changes in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

Sediment Available for Coastal Nourishment (Indicator #8142) - *this indicator is also a Nearshore Terrestrial indicator*

This indicator will assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and it will be used to estimate the amount of sediment available for transport to nourish coastal ecosystems.

PRESSURE

Sea Lamprey (Indicator #18)

This indicator will estimate sea lamprey abundance and assess their impact on other fish populations in the Great Lakes.

Phosphorus Concentrations and Loadings (Indicator #111)

This indicator will assess the total phosphorus levels and loadings in the Great Lakes, and it will be used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

Contaminants in Young-of-the-Year Spottail Shiners (Indicator #114)

This indicator will assess the levels of PBT chemicals in young-of-the-year spottail shiners, and it will be used to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

Contaminants in Colonial Nesting Waterbirds (Indicator #115)

This indicator will assess chemical concentration levels in a representative colonial waterbird, and it will be used to infer the impact of these contaminants on colonial waterbird physiology and population characteristics.

Atmospheric Deposition of Toxic Chemicals (Indicator #117)

This indicator will estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it will be used to infer potential impacts of toxic chemicals from atmospheric deposition on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Toxic Chemical Concentrations in Offshore Waters (Indicator #118)

This indicator will assess the concentration of priority toxic chemicals in offshore waters, and it will be used to infer the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Concentrations of Contaminants in Sediment Cores (Indicator #119)

This indicator will assess the concentrations of toxic chemicals in sediments, and it will be used to infer potential harm to aquatic ecosystems by contaminated sediments, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Contaminant Exchanges between Media: Air to Water and Water to Sediment (Indicator #120)

This indicator will estimate loadings of priority pollutants to the Great Lakes, and it will be used to infer the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Wastewater Pollution (Indicator #7059)

This indicator will assess the loadings of wastewater pollutants discharged into the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

4.2 Coastal Wetlands

Coastal Wetlands Definition
The extent of Great Lakes coastal wetlands fluctuates greatly with natural lake processes which can particularly affect the lake-side boundary. For SOLEC, the inland boundary is the extent of wetlands as far as the 100-year floodline of the Lakes (as described in the SOLEC 96 background paper "Coastal Wetlands of the Great Lakes").

Coastal wetlands differ from inland wetlands in that they are shaped by large-lake processes, including waves, wind tides, seiches, and especially seasonal and long-term fluctuations in water levels. They include emergent marshes, strand communities, wet meadows, submergent communities, swamps, and peatlands. They occur in a number of geomorphological settings: open shoreline, unrestricted bays, shallow sloping beaches, river deltas, restricted riverine settings, Lake-connected inlands, barrier beaches, and diked wetlands. The SOLEC 96 background paper "Coastal Wetlands of the Great Lakes" provides a detailed description of the types of coastal wetlands and the geomorphological settings in which they occur.

Indicating Health and Integrity
To select indicators of the health and integrity of coastal wetlands, the following definition of coastal wetland health was used:

- capability to self-maintain assemblages of organisms that have a composition and functional organization comparable to natural habitat;
- resiliency to natural disturbances; and
- risk factors or human-induced pressures at an "acceptable level".

Scale
For the purpose of SOLEC, the recommended indicators should be applicable basin-wide. The IJC suggests that an understanding of a system at any scale requires indicators of at least three scales: a) the level in question; b) the level above for context; and c) the level below for mechanisms. In the case of coastal wetland indicators we are considering indicators at the following scales: individual Lake basins, the Great Lakes basin, and a set of sites. Monitoring at sites will require a choice of representative sites.

Representative Wetland Sites
Representative sites have yet to be chosen for monitoring the recommended indicators. Ideally, sites should represent wetland distribution among the Lakes, and take into account influencing pressures, wetland types, and geomorphological settings. In part, the selection will be based on the representative reaches identified through the "Coastal Wetlands Biodiversity Investment Areas" paper. They should also include high quality (i.e., relatively pristine) reference sites to serve as baselines for comparison to the more degraded sites. It should be recognized, of course, that some parts of the Great Lakes basin no longer have any reference sites of this quality, and reference sites themselves will be degraded to some degree. This is particularly true of Lake Ontario, which has had regulated water levels for about 40 years.

4.2.1 The Indicator Selection Process

Potential coastal wetlands indicators were "mined" from eleven documents. Reviewing the documents and listing information for indicators related to wetland health yielded 330 potential indicators for further consideration. These were grouped into eleven categories: Area, Habitat, Vegetation, Community/Diversity, Benthos, Fish, Contaminants, Nutrients, Human/Land Use/Terrestrial, Species, and Physical Factor in order to identify and remove duplication. Because SOLEC primarily focuses on pressures and the state of the ecosystem, and does not make recommendations on programs, the coastal wetlands group did not actively seek out human activities indicators.

Based on the SOLEC criteria (Appendix 4), the indicators were ranked by the Coastal Wetlands expert panel and those that ranked low were no longer considered. The expert panel made recommendations of the best indicators, but in some cases additional indicators were suggested.

Currently there are 12 indicators in the Coastal Wetlands indicator list (one of which, 4861, is also grouped in the Nearshore Terrestrial core group).

4.2.2 Problems / Unresolved Issues

Difficulties Encountered with the Process
For SOLEC purposes, indicators need to have specific measures that can either utilize data being provided by an existing monitoring program or provide sufficient detail that a new monitoring program can be designed. However, few of the documents contained any significant information beyond the name of the indicator, and most of the indicator names were vague (e.g., quantity and quality of wetlands).

However, indicators clearly could not have been developed without first reviewing what others had done. With the indicators grouped into broad classes, they could be easily compared, modified, or combined. Thus, the process involved an additional step, but produced a proposed suite of indicators that the coastal wetlands group feels will allow an adequate assessment of the ecological health of Great Lakes coastal wetlands.

Unresolved Issues
Protocols for monitoring several of the indicators still need to be refined. The wide natural fluctuations associated with many features of Great Lakes coastal wetlands complicate the setting of desired endpoints. Some may require modifications. The method to select representative sites for monitoring also needs refinement.

The segregation of coastal wetlands from the other groups was necessary for a manageable process. This organization, however, hindered some broader ecosystem considerations. Positioned between the lakes and upland, and affected by processes in each, healthy coastal wetlands depend on healthy lake and watershed ecosystems. As such, coastal wetlands could be considered indicators of the health of the whole basin ecosystem (and so all that would be needed); or conversely, the health of the Land Use, Nearshore Terrestrial and Open and Nearshore Waters could indicate coastal wetland health (and wetland indicators would not be needed). These links and their implications for what is necessary and sufficient have not been explored.

In general, if there is broad agreement among the Great Lakes constituency on SOLEC indicators for coastal wetlands, organizations at all levels may be responsive to sharing monitoring expertise among themselves without any one organization taking an undue burden.

There are few existing monitoring programs for Great Lakes coastal wetlands. Efforts were made in the coastal wetlands group to select indicators for which there are existing data and monitoring programs, particularly for the pressure indicators. Many of the indicators will require new or improved monitoring programs. For the new programs to attain SOLEC's feasibility criterion, it is suggested that:

- Monitoring be conducted by volunteers, where possible. Volunteers would require training and adherence to monitoring protocols and quality assurance plans; however, this is true for professionals as well.
- Monitoring frequencies for each indicator will also need to be determined. While some indicators may need to be monitored several times a year, the more intensive (and expensive) monitoring may only need to be conducted every few years.
- Different organizations may be able to incorporate new protocols into their ongoing monitoring programs, without an inordinate increase in costs.

4.2.3 Coastal Wetland Indicators

STATE

Coastal Wetland Invertebrate Community Health (Indicator #4501)

This indicator will assess the diversity of the invertebrate community, especially aquatic insects, and it will be used to infer habitat suitability and biological integrity of Great Lakes coastal wetlands.

Coastal Wetland Fish Community Health (Indicator #4502)

This indicator will assess the fish community diversity, and it will be used to infer habitat suitability for Great Lakes coastal wetland fish communities.

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Coastal Wetland Fish (Indicator #4503)

This indicator will assess the combination of deformities, eroded fins, lesions and tumours (DELT index) in fish of Great Lakes coastal wetlands, and it will be used to infer ecosystem health of Great Lakes coastal wetlands.

Amphibian Diversity and Abundance (Indicator #4504)

This indicator will assess the species composition and relative abundance of frogs and toads, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically important component of wetland communities.

Wetland-Dependent Bird Diversity and Abundance (Indicator #4507)

This indicator will assess the wetland bird species composition and relative abundance, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

Coastal Wetland Area by Type (Indicator #4510)

This indicator will assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural variations.

Presence, Abundance and Expansion of Invasive Plants (Indicator #4513)

This indicator will assess the decline of vegetative diversity associated with an increase in the presence, abundance, and expansion of invasive plants, and it will be used as a surrogate measure of the quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

PRESSURE

Contaminants in Snapping Turtle Eggs (Indicator #4506)

This indicator will assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs, and it may be used to infer the extent of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

Sediment Flowing into Coastal Wetlands (Indicator #4516)

This indicator will assess the sediment load to coastal wetlands and its potential impact on wetland health.

Nitrate and Total Phosphorus Into Coastal Wetlands (Indicator #4860)

This indicator will assess the amount of nitrate and total phosphorus flowing into Great Lakes coastal wetlands, and it will be used to infer the human influence on nutrient levels in the wetlands.

Water Level Fluctuations (Indicator #4861) - *this is also a Nearshore Terrestrial indicator*

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

HUMAN ACTIVITY

Gain in Restored Coastal Wetland Area by Type (Indicator #4511)

This indicator will assess the amount of restored wetland area, and it will be used to infer the success of conservation and rehabilitation efforts.

4.3 Nearshore Terrestrial

4.3.1 The Indicator Selection Process

A process similar to the Coastal Wetlands group was followed to develop a proposed set of indicators of the health of the nearshore environment.

First, potential indicators were mined from reports and documents, most of which related to the Great Lakes, but a few reports had broader applications (see Appendix 7). With the help of an expert panel the initial list of 145 indicators was winnowed down by assessing against the basic criteria (necessary, sufficient and feasible), removing duplication, and combining or creating new indicators where necessary. This reduced the list quite considerably. Then each of the potential nearshore terrestrial indicators was described more fully.

Currently, there are 14 indicators in the Nearshore Terrestrial indicator list, 2 of which are also grouped in other core groups - 8142 is also grouped with the Nearshore and Open Waters indicators, and 4861 is also grouped with the Coastal Wetlands group.

The Indicator Framework

Indicators are provided to highlight physical, biological, and chemical stressors. Within the state categories, indicators are proposed both for habitat status, and for the health and stability of ecological communities/species. Human activities (responses) consider direct actions, such as recovery plans written or habitats protected.

Issues and Next Steps

A protocol will need to be developed for each of the selected indicators which will establish such details as:

- whether monitoring should take place across the entire nearshore area or in "sentinel sites" only;
- whether indicator results should be reported as trends over time, or in comparison to historical conditions or a defined target (such as RAP habitat targets);
- the degree to which existing monitoring programs and databases can be adapted to each indicator.

4.3.2 Nearshore Terrestrial Indicators (within 1 kilometre of shore)

STATE

Indicators related to habitats:

Extent and Quality of Nearshore Natural Land Cover (Indicator #8136)

This indicator will assess the amount of natural land cover that falls within 1 km of the shoreline, and it will be used to infer the potential impact of artificial coastal structures, including primary and secondary home development, on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

Indicators related to health and stability of ecological communities/species:

Area, Quality, and Protection of Special Lakeshore Communities (Indicator #8129)

This indicator will assess the changes in area and quality of the twelve special lakeshore communities, and it will be used to infer the success of management activities associated with the protection of some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore.

Nearshore Land Use (Indicator #8132)

This indicator will assess the types and extent of major land uses within 1 km from shore, and it will be used to identify real or potential impacts of land use on significant natural features or processes, particularly on the twelve special lakeshore communities.

Nearshore Species Diversity and Stability (Indicator #8137)

This indicator will measure the composition and abundance of plant and wildlife species over time within the nearshore area and indirectly measure adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.

Sediment Available for Coastal Nourishment (Indicator #8142) - *this is also a Nearshore Waters Indicator*

This indicator will assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and it will be used to estimate the amount of sediment available for transport to nourish coastal ecosystems.

PRESSURE

Indicators related to physical stressors:

Water Level Fluctuations (Indicator #4861) - *this is also a Coastal Wetland indicator*

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

Extent of Hardened Shoreline (Indicator #8131)

This indicator will assess the amount of shoreline habitat altered by the construction of shore protection, and it will be used to infer the potential harm to aquatic life in the nearshore as a result of conditions (i.e., shoreline erosion) created by habitat alteration.

> For the purposes of applying these indicators, the nearshore terrestrial environment was defined as those lands within approximately one kilometer of the Great Lakes shoreline.

Artificial Coastal Structures (Indicator #8146)

This indicator will assess the number of artificial coastal structures on the Great Lakes, and it will be used to infer potential harm to coastal habitat by disruption of sand transport.

Indicators related to biological stressors:

Nearshore Plant and Animal Problem Species (Indicator #8134)

This indicator will assess the type and abundance of plant and wildlife problem species in landscapes bordering the Great Lakes, and it will be used to identify the potential for disruption of nearshore ecological processes and communities.

Indicators related to chemical stressors:

Contaminants Affecting Productivity of Bald Eagles (Indicator #8135)

This indicator will assess number of fledged young, number of developmental deformities, and the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers. The data will be used to infer the potential harm to other wildlife and human health through the consumption of contaminated fish.

Contaminants Affecting the American Otter (Indicator #8147)

This indicator will assess the contaminant concentrations found in American otter populations within the Great Lakes basin, and it will be used to infer the presence and severity of contaminants in the aquatic food web of the Great Lakes.

HUMAN ACTIVITIES (RESPONSE)

Community / Species Plans (Indicator #8139)

This indicator will assess the number of plans that are needed, developed, and implemented to protect, maintain or restore high quality, natural nearshore communities and federally listed endangered, threatened, and vulnerable species. This indicator will be used to infer the degree of human stewardship toward these communities and species.

Shoreline Management Under Integrated Management Plans (Indicator #8141)

This indicator will assess the amount of Great Lakes shoreline managed under an integrated management plan, and it will be used to infer the degree of stewardship of shoreline processes and habitat.

Protected Nearshore Areas (Indicator #8149)

This indicator will assess the kilometers/miles of shoreline in six classes of protective status. This information will be used to infer the preservation and restoration of habitat and biodiversity, the protection of adjacent nearshore waters from physical disturbance and undesirable inputs (nutrients and toxics), and the preservation of essential habitat links in the migration (lifecycle) of birds and butterflies.

4.4 Land Use

4.4.1 The Indicator Selection Process

Poor land use by humans is the predominant cause of environmental problems in the ecosystems of the Great Lakes basin. In spite of considerable evidence of the significant disadvantages of urban sprawl, this development form continues to be the most commonly applied approach to new development. Clearly, as was concluded in SOLEC 96, there is a need for better ways of influencing decision-makers in the Great Lakes basin to make environmentally informed development decisions. The land use indicators are intended to meet that need.

Several documents and reports were consulted to develop an initial list of Land Use indicators (see Appendix 7). Using the basic criteria of necessary, sufficient and feasible, the list was then shortened. An expert panel was formed to review, revise and add further detail to these indicators.

Currently, there are eight indicators grouped in the Land Use core group.

> Poor land use is a major source of environmental stress in the Great Lakes basin ecosystem.

4.4.2 Land Use Indicators

STATE

Urban Density (Indicator #7000)

This indicator will assess the human population density in the Great Lakes basin, and it will be used to infer the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

Habitat Adjacent to Coastal Wetlands (Indicator #7055)

This indicator will provide an index of the quality of adjoining upland habitat which can have a major effect on wetland biota, many of which require upland habitat for part of their life cycle.

Habitat Fragmentation (Indicator #8114)

This indicator will assess the amount and distribution of natural habitat remaining within Great Lakes ecoregions, and it will be used to infer the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

PRESSURE

Land Conversion (Indicator #7002)

This indicator will assess the changes in land use within the Great Lakes basin, and it will be used to infer the potential impact of land conversion on Great Lakes ecosystem health.

Mass Transportation (Indicator #7012)

This indicator will assess the percentage of commuters using public transportation, and it will be used to infer the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and pollution creation.

HUMAN ACTIVITIES (Response)

Brownfield Redevelopment (Indicator #7006)

This indicator will assess the acreage of redeveloped brownfields, and it will be used over time to evaluate the rate at which society rehabilitates and reuses former developed land sites that have been degraded by poor use.

Sustainable Agriculture Practices (Indicator #7028)

This indicator will assess the number of Environmental and Conservation farm plans, and it will be used to infer environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Green Planning Process (Indicator #7053)

This indicator will assess the number of municipalities with environmental and resource conservation management plans in place, and it will be used to infer the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation and natural area preservation.

4.5 Human Health

4.5.1 The Indicator Selection Process

There is interest in having indices or indicators for monitoring progress or changes in human health as it relates to the Great Lakes environment. These can be either changes over time or comparisons between geographic regions. The premise is that as environmental conditions change in the Great Lakes basin, so does the state of the health of the population in that region. Such indicators are also needed to assess the effectiveness of health and environment policies and actions in protecting or improving the health of the Great Lakes basin population.

...it is clear that no single indicator is adequate to establish associations and trends between human health and the environment.

With our present knowledge, it is clear that no single indicator is adequate to establish associations and trends between human health and the environment. Consequently, indicators were chosen which, as a whole, serve to monitor human health as it relates to the Great Lakes environment. The indicators chosen are by no means exhaustive but represent an initial effort at establishing health-related indicators for the Great Lakes population. As research progresses in this area, other indicators can be added to the current suite of indicators, or may replace them altogether.

For practical purposes, this effort to develop health indicators for SOLEC has focused primarily on indicators of human exposure to environmental contaminants along with some geographic patterns and trends in disease incidence. The indicators of exposure are either contaminant levels measured in human tissues, such as breast milk or blood, estimates of daily intake of persistent contaminants by the Great Lakes population, or contaminant levels in air, drinking water and recreational water. The contribution of these exposures as causative factors in disease, such as cancer and birth defects, can be difficult to identify. However, the analysis of geographic patterns and trends in incidence rates can serve to identify potential areas of concern and may lead to testable hypotheses regarding the correlation of environmental exposure with human disease.

The extensive initial list of indicators identified by the Human Health Core Group was reduced by eliminating those indicators that were thought not to be informative, either because 1) specific exposure media were unlikely to make a relatively significant contribution to overall contamination exposure levels, 2) some contaminants were unlikely to be detected in specific media, or 3) difficulties in obtaining information in a comprehensive manner. A greater weight was given to those indicators that represented data available from current monitoring programs, to those indicators that were supported by an existing database, and to those indicators that were more likely to provide information that could be used to evaluate the relationships between contaminant exposures and health. Currently, there are nine indicators in the Human Health indicators list.

Although there exist many other indicators of health such as life expectancy, birth weight and well being, these were not included in the final list because the impact of current environmental conditions on these indicators is either not well understood or not well developed. In many cases, improvements in these indicators have occurred even during times of changing environmental quality due to population growth and industrialization in the Great Lakes basin. Advances in public health, medicine, access to health care, education, and economy contributed greatly to improvements in the health of the population. However, as we gain more information on the relationships between these parameters and the environment, their inclusion as future indicators may be warranted.

4.5.2 Human Health Indicators

STATE

Geographic Patterns and Trends in Disease Incidence (Indicator #4179)

This indicator will assess geographical and temporal patterns in disease incidences in the Great Lakes basin population, and it will also b e used to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.

PRESSURE (Indicators of Exposure)

Contaminants in Recreational Fish (Indicator #0113)

This indicator will assess the levels of PBT chemicals in fish, and it will be used to infer the potential harm to human health through consumption of contaminated fish.

E. coli and Fecal Coliform Levels in Nearshore Recreational Waters (Indicator #4081)

This indicator will assess coliform contaminant levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and it will be used to infer potential harm to human health through body contact with nearshore recreational waters.

Contaminants in Edible Fish Tissue (Indicator #4083)

This indicator will assess the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and it will be used to infer the exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

Chemical Contaminant Intake From Air, Water Soil and Food (Indicator #4088)

This indicator will estimate the daily intake of PBT chemicals from all sources, and it will be used to evaluate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Drinking Water Quality (Indicator #4175)

This indicator will assess the chemical and microbial contaminant levels in drinking water, and it will be used to evaluate the potential for human exposure to drinking water contaminants and the efficacy of policies and technologies to ensure safe drinking water.

Air Quality (Indicator #4176)

This indicator will monitor the air quality in the Great Lakes ecosystem, and it will be used to infer the potential impact of air quality on human health in the Great Lakes basin.

Chemical Contaminants in Human Tissue (Indicator #4177)

This indicator will assess the concentration of PBT chemicals in human tissues, and it will be used to infer the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

Radionuclides (Indicator #4178)

This indicator will assess the concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and it will be used to estimate the potential for human exposure to artificial radionuclides.

4.6 Societal

In the period between SOLEC 98 and Spring 1999 the decision was made to broaden the scope of the Stewardship Core Group to include socio-economic and other societal indicators. Since this group now housed the indicators of society, it was renamed "Societal" in order to reflect this change.

Stewardship and Sustainability

A "steward" is someone who manages the affairs of a household or estate on behalf of an employer, owner, or beneficiary. "Stewardship" is a process requiring competence, vigilance, and an ethic of responsibility for the condition of that which is being looked after.

Stewardship is not sustainability, but sustainability provides the conceptual structure for which the process of stewardship is pursued. That is, stewardship activities are intended to achieve a sustainable future — *a balance between environmental integrity, economic viability, and social well-being.* In this regard, stewardship is closely related to ecosystem-based management which seeks to sustain ecosystem integrity across time. Thus, *sustainability* is the expression of the overall "desirable end state" and *ecosystem management* describes the basic strategy employed in *the process of stewardship.*

For SOLEC, sustainability is implicit within the entire set of proposed indicators, and a separate set of indicators for sustainability would be redundant. A comprehensive set of indicators to assess human activities, or "program responses," however, would reflect our collective stewardship of the Great Lakes ecosystem - our individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment.

The initial process to identify indicators of stewardship for SOLEC 98 was similar to that for the other groups, but with inconclusive results. Few documents were found that contained indicators for stewardship in the Great Lakes. Although many ideas had been generated, there were very few appropriate stewardship indicators, and they were quite general.

> ...stewardship activities are intended to achieve a sustainable future — a balance between environmental integrity, economic viability, and social well-being.

The approach described in Section 4.6.1 was developed just prior to SOLEC 98. Due to the late change in emphasis, *neither the approach nor the proposed indicators had received extensive review from an expert panel or other stakeholders prior to SOLEC 98.* It is anticipated that a full suite of Societal indicators will be presented at SOLEC 2000. Some of these indicators will include examples of their applications.

Socio-Economics and Other Aspects of Society

The health of the environment is closely tied to a regions' economy and societal values. In the case of the Great Lakes region, an international border separates distinct political traditions and national cultures, but despite this, an integrated economy has developed - one with a strong resource base and manufacturing complex. However, increased competition from both domestic and global economies, a maturing industrial infrastructure, continued urbanization and the environmental impacts of economic and social activity are forcing a new development path - one that both supports the economy and preserves the environment.

Integrated management of society as part of the ecosystem requires organization of human activities consistent with the need to respect other ecosystem components. For example, the callous creation and discharge of waste materials may impact on the habitat of other species, result in contamination and other health problems.

4.6.1 The Indicator Selection Process

Stewardship Indicators

This approach assumes that the existence of partnerships, their coverage of the Great Lakes basin, their organizational capacities, and the "richness" of their memberships, will lead to improvements in the state of the environment and to reductions of environmental pressures or threats. In addition, local partnerships are framed and supported by citizen interest and involvement in stewardship initiatives, as well as governmental adoption and endorsement of ecosystem management and sustainability principles. These proposed stewardship indicators would track the development and capacities of partnerships engaged in ecosystem management activities in the Great Lakes basin, but not the underlying motivations or other reasons for actions and responses, nor the actual environmental changes brought about by these actions.

Socio-Economic and Other Society Indicators

Some of the indicators (such as economic prosperity, dollars allocated to Great Lakes programs and societal values (like aesthetics)) did not fit very well in their original core group but belonged in a group looking at indicators of society. This resulted in the expansion of the Stewardship group to a Societal group. The socio-economic section of the suite of Great Lakes indicators is in the early stages of development and further work is needed. It is hoped that in the future an indicator for social well being can be included here.

4.6.2 Societal Indicators

STATE

Aesthetics (Indicator #7042)

> This indicator will assess the amount of waste and decay around human activities in the Great Lakes basin, and it will be used to infer the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

Economic Prosperity (Indicator #7043)

> This indicator will assess the unemployment rates within the Great Lakes basin, and it will be used in association with other Societal indicators to infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

PRESSURE

Water Withdrawal (Indicator #7056)

This indicator will assess the amount of water used in the Great Lakes basin per capita, and it will be used to infer the amount of wastewater generated and the demand for resources to pump and treat water.

Energy Consumption (Indicator #7057)

This indicator will assess the amount of energy consumed in the Great Lakes basin per capita, and it will be used to infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

Solid Waste Generation (Indicator #7060)

This indicator will assess the amount of solid waste generated per capita per capita in the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

HUMAN ACTIVITIES (Response)

Capacities of Sustainable Landscape Partnerships (Indicator #3509) - *unchanged from SOLEC 98*

This indicator assesses the organizational capacities required of local coalitions to act as full partners in ecosystem management initiatives. It includes the enumeration of public-private partnerships relating to the pursuit of sustainable ecosystems through environmental management, staff, and annual budgets.

Organizational Richness of Sustainable Landscape Partnerships (Indicator #3510) - *unchanged from SOLEC 98*

This indicator assesses the diversity of membership and expertise included in partnerships. Horizontal integration is a description of the diversity of partnerships required to address local issues, and vertical integration is the description of federal and state/provincial involvement in place-based initiatives as full partners.

Integration of Ecosystem Management Principles Across Landscapes (Indicator #3511) - *unchanged from SOLEC 98*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted ecosystem management guiding principles in place-based resource management programs.

Integration of Sustainability Principles Across Landscapes (Indicator #3512) - *unchanged from SOLEC 98*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted sustainability guiding principles in place-based resource management programs.

Citizen/Community Place-Based Stewardship Activities (Indicator #3513) - *unchanged from SOLEC 98*

Community activities that focus on local landscapes/ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a "a sense of place." This indicator, or suite of indicators, will reflect the number, vitality and effectiveness of citizen and community stewardship activities.

Financial Resources Allocated to Great Lakes Programs (Indicator #8140)

This indicator will measure the amount of dollars spent annually on Great Lakes programs and indirectly measure the responsiveness of Great Lakes programs by determining the adequacy of annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

4.7 Unbounded Indicators

Several proposed indicators do not fit neatly into any of the seven SOLEC ecological categories (open waters, nearshore waters, coastal wetlands, nearshore terrestrial, land use, human health, and societal). These categories were selected to be consistent with the themes and papers of the two previous SOLECs, and they provide an organizational framework for selecting and reviewing indicators. The indicators could have been organized differently (for example, "fish, fauna, flora, water, land, air" - and, in fact, they have been sorted this way in Appendix 3, Relevancies), however, it is likely that some indicators would still transcend the group boundaries. For example, indicators related to issues such as climate change will affect all the groups yet truly belong in none of them.

Throughout the selection process these indicators were recognized and discussed. In some cases they were kept with the Core Group that originally nominated them, but in other cases they were transferred to another group that appeared to be more relevant. The Indicators Group avoided the creation of the category "miscellaneous" so that each indicator would receive the attention of at least one group, and none would become orphans.

However, for clarity of organization and presentation of the proposed indicators, the creation of an additional category called "Unbounded" was found to be useful. These indicators may have application to more than one of the organizing categories, or they may reflect issues that affect the Great Lakes but have global origins or implications.

Reviewers please note that the indicators in the Unbounded group have yet to receive an intensive review. We welcome your comments and suggested improvements for these indicators.

STATE

Breeding Bird Diversity and Abundance (Indicator #8150)

This indicator will assess the status of breeding bird populations and communities, and it will be used to infer the health of breeding bird habitat in the Great Lakes basin.

Threatened Species (Indicator #8161)

This indicator will assess the number, extent and viability of threatened species, which are key components of biodiversity in the Great Lakes basin, and it will be used to infer the integrity of ecological processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

PRESSURE

Acid Rain (Indicator #9000)

This indicator will assess the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and it will be used to infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.

Global Warming: Number of Extreme Storms (Indicator #4519)

This indicator will assess the number "extreme storms" each year, and it will be used to infer the potential impact on ecological components of the Great Lakes of increased numbers of storms due to climate change.

Global Warming: First Emergence of Water Lilies in Coastal Wetlands (Indicator #4857)

This indicator will assess the change over time in first emergence dates of water lilies as a sentinel of climate change affecting the Great Lakes.

Global Warming: Ice Duration on the Great Lakes (Indicator #4858)

This indicator will assess the temperature and accompanying physical changes to each lake over time, and it will be used to infer potential impact of climate change on wetlands.

Exotic Species (Indicator #9002)

This indicator will assess the presence, abundance and distribution of invasive exotic species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. *This indicator is under development. It has been added to the SOLEC list in response to suggestions from multiple reviewers of the Version 3 list of SOLEC indicators.*

Appendix 1 — Descriptor Information for Indicators in the SOLEC Indicator Suite

The following pages include more detailed information on each of the proposed indicators.

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Fish Habitat (Indicator ID: 6)

Measure

1) Quality and area of aquatic habitat (e.g., shore, spawning shoals, tributaries, wetlands, etc.) and 2) population of sentinel fish species. For example, the measures for tributary quality could include the number of dams, number of miles of river channel that is impounded, number of miles of (formerly) high-gradient stream channel that is impounded, and the number of miles between the river mouth and the first dam. The number and location of fish passage facilities (up- and downstream) that could be used successfully by species or communities of concern (for example, lake sturgeon, or other anadromous fishes listed in FCGO) could also serve as measures.

Purpose

This indicator will assess the quality and amount of aquatic habitat in the Great Lakes ecosystem, and it will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

Ecosystem Objective

This indicator addresses the general Fish Community Goals and Objectives (FCGO) to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. Annex 2 of the GLWQA calls for the restoration of lost or damaged habitat. The indicator also supports the policy position of the Great Lakes Fishery Commission (GLFC), Habitat Advisory Board, presented in their 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes.

Endpoint

The endpoints will need to be specific to habitat types and FCGO. In the Great Lakes and connecting channels, for example, the U.S. Environmental Protection Agency and Ontario Ministry of Environment numerical guidelines for dumping of contaminated dredged sediments can be used to protect aquatic habitat quality.

Features

This indicator will measure/calculate changes in aquatic habitat by area, by type, by location, by Lake, and by Biodiversity Investment Areas. Significant losses and degradation of aquatic habitat have occurred in the Great Lakes aquatic ecosystem since the late 1800s when European settlement of the region was completed. Logging, navigation projects, dam construction, shoreline development, agriculture, urbanization, municipal and industrial waste disposal, and water withdrawal by power generation facilities for once-through cooling have all acted to reduce the amount and quality of aquatic habitat in the system. These affected habitats include the Great Lakes proper, their connecting channels and coastal wetlands, and the tributaries that provide linkages with inland aquatic habitats and terrestrial habitats via the surface water continuum.

Wetland losses in the region have been reasonably well documented and quantified, but losses of the other major habitat types have not. Recent efforts to relicense hydropower dams in the United States have led to a reconsideration of the habitat losses associated with these dams and a useful picture is emerging which allows an assessment of the adverse impacts of habitat fragmentation on anadromous and resident stream-fish communities. Data for tributary habitat are being developed in connection with FERC dam relicensing procedures in the United States. Data are presently available for Michigan, New York State, and Wisconsin.

Large volumes of water are withdrawn from the Great Lakes and their connecting channels for use by industry and municipalities. Steam-electric power plants using once-through cooling, and pumped-storage hydropower plants withdraw the greatest volumes of water. Fish of all sizes are entrained with this water and substantial mortality occurs basin-wide among the entrained population. Rates of water withdrawal and associated fish mortality rates are known for existing steam-electric power plants using once-through cooling and for pumped-storage hydropower plants. Reduction in water withdrawal rates or the addition of effective screening devices at existing facilities would reflect an improvement in fish habitat, and hence a reduction in fish entrainment mortality.

Illustration

Limitations

Restoration ecology is an emerging scientific discipline requiring an understanding of multiple disciplines and partnerships. Comprehensive, detailed habitat inventory, classification, and mapping of Great Lakes aquatic habitats has not been undertaken. Much more research will be required to recognize critical fish habitat and to understand the relationship between quantity of habitat and aquatic production. Interpretation of habitat measurements is confounded by issues such as interacting species and connectivity of habitat between life stages.

Interpretation

Dam removal, switching from peak-power generating flow mode to run-of-the-river flow mode, and provision of fully functional upstream and downstream fish passage facilities consistent with state management strategies or FCGO would be considered to be rehabilitation of habitat and beneficial to the riverine and anadromous fish communities using dammed tributaries.

Comments

Further development and ratification of the Great Lakes Fishery Commission, Habitat Advisory Board, 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes should contribute significantly to furthering the goals of aquatic habitat protection and restoration in the Great Lakes basin.

Indicators 4510 & 4511 contribute to this indicator, as does indicator 72. Sentinel species should be the same for each of these indicators.

Unfinished Business

- Need to develop a list of sentinel fish species.
- Quantifiable endpoints and/or reference values need further development work.
- The method of graphically displaying this indicator needs to be determined. Will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?
- There needs to be more information added to help better understand the trends presented by this indicator.

Relevancies

Indicator Type: state
Environmental Compartment(s): water, fish
Related Issue(s): habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**, coastal wetlands
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 25, 2000

Salmon and Trout (Indicator ID: 8)

Measure

1) Productivity, yield, or harvest of Pacific salmon, rainbow trout and brown trout using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) populations of these stocked and naturally produced fish.

Purpose

This indicator will show trends in populations of introduced trout and salmon populations, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

Ecosystem Objective

"To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem."[1]

In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint

The current Fish Community Goals and Objectives (FCGO) for introduced trout and salmon species establish harvest or yield targets consistent with FCGO for lake trout restoration, and in Lake Ontario, for Atlantic salmon restoration. The following index targets for introduced trout and salmon species were provided in the FCGO for the listed lake.

Lake Ontario (1999): *Salmon and trout catch rates in recreational fisheries continuing at early-1990s levels.*

Lake Erie (1999 draft): *Manage the eastern basin to provide sustainable harvests of valued fish species, including . . . lake trout, rainbow trout and other salmonids.*

Lake Huron (1995): *A diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.*

Lake Michigan: *A diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout.*

Lake Superior (1990): *Achieve . . . an unspecified yield of other salmonid predators, while maintaing a predator/prey balance which allows normal growth of lake trout.*

Salmonine abundance should be great enough to keep alewife abundance below levels associated with the suppression of native fishes, but should also be below levels where predatory demand threatens the forage base and the integrity of the system.

Features

This indicator will assess trends of Pacific salmon and rainbow and brown trout populations over time. These species were introduced into the Great Lakes ecosystem, are reproducing successfully in portions of the system, and can be considered to be permanent, "naturalized" components of the system. Stocking of these species continues to augment natural reproduction and enhance fishing opportunities, which is generally viewed favourably by the angling public. However, diversification of the salmonine component of the fish community is a significant departure from the historic dominance by lake trout; the impacts of diversification on native species and ecosystem function is not yet fully understood.

Illustration

Limitations

The data for this indicator are collected annually by the states for certain segments of the fishery (e.g., Michigan's segment of the Lake Michigan charter boat fishery) and are available for reporting, but there is no coordinated, basin-wide data collection program. Reporting occurs as news releases and as reports to the Lake Committees of the Great Lakes Fishery Commission. More analysis of existing data and evaluation of management alternatives through mathematical modelling is needed before more detailed species-by-species harvest can be defined.

Interpretation

Comments

[1] Great Lakes Fishery Commission. 1997. A Joint Strategic Plan for Management of Great Lakes Fisheries, Ann Arbor, Mi.

Pacific salmon and Rainbow and Brown trout are introduced species. Some of these are now naturalized but stocking still occurs. Atlantic salmon, which were native to Lake Ontario, have been introduced at times to the other four Great Lakes. Atlantic salmon introductions to the upper four Great Lakes should be treated as potentially beneficial range extensions of the species within the basin. This valuable species is in decline in most of its historical Western Atlantic range, and the establishment of naturalized populations in the Great Lakes would help ensure the survival of the Western Atlantic gene pool.

The salmonine community will consist of both wild and planted salmonines and exhibit increasing growth of, and reliance on, natural reproduction. Short-term restrictions of harvest may be required to achieve long-term goals of natural reproduction.

Manipulation of the mix of salmonines should, in theory, result in higher catches than those produced solely by lake trout. The lake trout historically inhabited the whole water column, but its use of the pelagic food web (although substantial) could not have been as efficient as the contemporary species mix of lake trout and of pelagic piscivores--Pacific salmon, brown trout, and rainbow trout.

With finite prey and habitat resources for salmonine production, each species will exist at some expense to the others.

Fin clips were used in past to mark introduced fish. Coded wire tags are used mostly on fingerlings, currently. Several other marking techniques are used less frequently. Otolith, scale, and fin ray abnormalities used for fish smaller at release and for F2 and later recoveries.

Unfinished Business

- There needs to be more information on the spatial and temporal trends this indicator will describe, as well as potential variability in the data.
- The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?
- There needs to be more information added to help better understand the trends presented by this indicator.

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised

March 7, 2000

Walleye and Hexagenia (Indicator ID: 9)

Measure

Abundance, biomass, or annual production of walleye and burrowing mayfly (Hexagenia spp.) populations in historical, warm-coolwater, mesotrophic habitats of the Great Lakes. Presence or absence of a Hexagenia mating flight (emergence) in late June-July in areas of historical abundance.

Purpose

This indicator will show the status and trends in walleye and Hexagenia populations, and it will be used to infer the basic structure of warm-coolwater predator and prey communities, the health of percid populations, and the health of the Great Lakes ecosystem.

Ecosystem Objective

Historical mesotrophic habitats should be maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with walleye as the top aquatic predator of the warm-coolwater community and Hexagenia as a key benthic invertebrate organism in the food chain. (Paraphrased from **Final Report of the Ecosystem Objectives Subcommittee**, 1990, to the IJC Great Lakes Science Advisory Board.) In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint

Appropriate quantitative measures of abundance, yield, or biomass should be established as reference values for self-sustaining populations of walleye in mesotrophic habitats in each lake. The indicator for walleye can be based on the following index target abundances provided in the FCGOs:

Lake Huron (1995): *Reestablish and/or maintain walleye . . . with populations capable of sustaining a harvest of 0.7 million kg*
Lake Michigan (1995): *Expected annual yield: 0.1-0.2 million kg*
Lake Erie (1999): *Manage the western, central and eastern basin ecosystems to provide sustainable harvests of valued fish species, including walleye . . .*
No reference values available for Lakes Superior and Ontario.

The walleye is a highly valued species that is usually heavily exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

Features

The historical dominance of walleye and Hexagenia in mesotrophic habitats in the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production and reestablishing self-sustaining populations of walleye and Hexagenia throughout their native range in the basin will help ensure dominance of these two species in the ecosystem and the maintenance of a desirable and balanced aquatic community in warm-coolwater mesotrophic habitats. Hexagenia area major integrator between detrital and higher levels in food web. Hexagenia are highly visible during emergence in June-July and the public can easily use the species as an indicator to judge ecosystem health in areas where it is now abundant or was historically abundant but now is absent. Historical data can be used to develop status and trend information on walleye and Hexagenia populations. Commercial catch records for walleye in the Great Lakes extend back to the late 1800s; recreational catch data and assessment fishing data supplement these commercial catch records in some areas in recent years and are especially useful in areas where the commercial fishery for the species has been closed. Sediment cores from Lake Erie show major trends in abundance of Hexagenia extending back to about 1740 and other data are available to document more recent and present levels of abundance in Lake Erie and other parts of the basin.

Illustration

Limitations

Walleye abundance can be reduced by overfishing; harvest restrictions designed to promote sustained use are required if the species is to be used as an indicator of ecosystem health. The walleye element of the indicator cannot reliably diagnose causes of degraded ecosystem health. Hexagenia are extirpated at moderate levels of pollution, thus do not show graded response to severe levels of pollution. Target reference values for the indicator have not been developed for all major Great Lakes mesotrophic habitats.

Interpretation

The desired trend is increasing dominance to historical levels of the indicator species in mesotrophic habitats throughout the basin. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. The presence of an annual Hexagenia mating flight (emergence) in late June-early July can also be used by the public and other non-technical observers as a specific indicator of good habitat quality, whereas the lack of a mating flight in areas where the species was historically abundant can be used as an indicator of degraded habitat. High Hexagenia abundance is strongly indicative of uncontaminated surficial sediments with adequate levels of dissolved oxygen in the overlying water columns.

Probable causative agents of impairment for Hexagenia include excess nutrients and pollution of surficial sediments with metals and oil.

Comments

Hexagenia were abundant in major mesotrophic Great Lakes habitats including Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), Lake St. Clair, western and central basins of Lake Erie, Bay of Quinte (Lake Ontario), and portions of the Great Lakes connecting channels. Eutrophication and pollution with persistent toxic contaminants virtually extinguished Hexagenia populations throughout much of this habitat by the 1950s. Controls on phosphorus loadings resulted in a major recovery of Hexagenia in western Lake Erie in the 1990s. Reduction in pollutant loadings to Saginaw Bay has resulted in limited recovery of Hexagenia in portions of the Bay. Hexagenia production in upper Great Lakes connecting channels shows a graded response to heavy metals and oil pollution of surficial sediments.

Hexagenia should be used as a benthic indicator in all mesotrophic habitats with percid communities and percid FCGOs. Contaminant levels in sediment that meet USEPA and OMOE guidelines for "clean dredged sediment" and IJC criterion for sediment not polluted by oil and petrocarbons will not impair Hexagenia populations. There will be a graded response to concentrations of metals and oil in sediment exceeding these guidelines for clean sediment. Reductions in phosphorus levels in formerly eutrophic habitats are usually accompanied by recolonisation by Hexagenia, if surficial sediments are otherwise uncontaminated.

Unfinished Business

- Has a quantitative endpoint for Hexagenia populations been developed? If not, then further development work is necessary for this indicator.
- The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends in walleye and Hexagenia populations over time?

Relevancies

Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

Last Revised

March 7, 2000

Preyfish Populations (Indicator ID: 17)

Measure

Abundance and diversity, as well as age and size distribution, of preyfish species (i.e., deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives) in each lake.

Purpose

This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

Ecosystem Objective

To maintain a diverse array of preyfish populations to support healthy, productive populations of predator fishes as stated in the FCGOs for each lake. For Lake Michigan, the Planktivore Objective (GLFC, 1995) states: Maintain a diversity of prey (planktivore) species at population levels matched to primary production and to predator demands. This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies and to Annex 2 of the GLWQA.

Endpoint

This indicator will refer to index target abundances for preyfish — the values used to regulate the amount of predator fish stocked in each lake — provided in the FCGO for each lake as quantitative reference values that represent the necessary diversity and structure of the preyfish community. Lakes Huron, Michigan and Superior provide general guidelines for prey species prioritizing species diversity and a return to historical population levels. Lake Michigan FCGO proposed a lakewide preyfish biomass of 0.5 to 0.8 billion kg (1.2 to 1.7 million lbs.). Lake Ontario FCGO proposed an average annual biomass of 110 kilogram/hectare for the production of top predators.

Features

An inadequate preyfish base might signal the need for reduction in predator species abundance by increasing harvest or reducing number of predator fish stocked. If preyfish populations also support a major recreational or commercial fishery, or are reduced significantly by entrainment mortality at water withdrawal sites in the Great Lakes, curtailment of these losses would be appropriate. Maintaining species diversity in the preyfish base may also require more detailed consideration and management of the predator species mix in the lake. Preyfish populations in each of the lakes is currently monitored on an annual basis. Changes in species composition, as well as changes in size and age composition of the major preyfish species, are available for review from long-term databases.

Illustration

Lake-wide annual trends are displayed for each lake in bar chart format. A GIS-based reporting system is under development that will show annual trends at multiple sampling locations within each lake.

Limitations

Index target abundances, the quantitative reference values for this indicator, have not been established for all preyfish species in each lake.

Interpretation

Comments

Diversity in preyfish species imparts some overall stability to the forage base by minimizing the effects of year-to-year variations typically experienced by a single species; therefore, managing the preyfish resource for the exclusive benefit of a single preyfish species, such as alewife, is not recommended. A substantial component of native preyfish species should be maintained, especially if new research implicates thiaminase in introduced preyfish species, such as alewives and rainbow smelt, as a major factor contributing to reproductive failure in lake trout and Atlantic salmon in the Great Lakes. There is interest expressed in some FCGOs in protecting or reestablishing rare or extirpated deepwater cisco preyfish species in their historic habitats in the Great Lakes. This should be reflected in future reference values for affected lakes.

Unfinished Business

- A discussion on how this indicator will be interpreted using the endpoint(s) is needed. For example, this indicator may need to be analyzed in conjunction with an indicator on primary production and/or predator species abundance and diversity.

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters, nearshore waters**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised
March 8, 2000

Sea Lamprey (Indicator ID: 18)

Measure

Number of spawning run adult sea lampreys; wounding rates on large salmonids.

Purpose

This indicator will estimate sea lamprey abundance and assess their impact on other fish populations in the Great Lakes.

Ecosystem Objective

This indicator relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies: *To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem.*

The 1955 Convention of Great Lakes Fisheries created the Great Lakes Fishery Commission "to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention area."

In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint

This indicator will refer to the index target abundances for sea lamprey populations provided in the most current Fish Community Goals and Objectives (FCGO) for each lake. The following objectives are listed in the FCGO with the date of issue for each lake.
Lake Huron (1995): *75 % reduction by 2000; 90 % reduction by 2010.*
Lake Ontario (1999): *Suppression of sea lamprey populations to early-1990s levels, and maintaining sea lamprey marking rates <0.02 marks per fish for lake trout.*
Lake Michigan (1995): *Suppress the sea lamprey to allow the achievement of other fish-community objectives.*
Lake Erie (1999 draft): *Unspecified Objective.*
Lake Superior (1990): *50 % reduction in parasitic-phase sea lamprey abundance by 2000; 90 % reduction in parasitic-phase sea lamprey abundance by 2010.*

Features

Control of sea lamprey populations is necessary to achieve other fish-community objectives because of the high mortality rates inflicted by lampreys on other fish. Spawning-run data are collected annually in selected streams; wounding data are collected annually in each lake. Long-term status and trend data are available.

Illustration

Annual status and trend data on sea lamprey abundance and wounding rates are displayed in bar charts and tables by geographic area of interest.

Limitations

Spawning-run estimates of parasitic populations must be based on a representative sampling of streams and must include large rivers. Reliable trapping and run estimates are often difficult or impossible to make for large rivers. Direct mark and recapture data for parasitic or larval phase sea lampreys is needed to provide better estimates and error terms, but these reliable, direct estimates may only be obtained in areas of high population abundance where large numbers of individuals can be marked and recaptured. Explicit estimates of variance is critical. Relating estimates of the spawning population to the resulting parasitic population assumes insignificant or at least constant mortality between the parasitic and spawning phases.

Wounding rates may be influenced by the abundance of prey in the suitable size range and may vary among major prey species depending on the mix of these fishes in an area. The season of data collection (e.g., spring or fall) affects the interpretation of the measure and must be kept constant. Classification of sea lamprey wounds (i.e., wounds or scars, Type A or Type B) is subjective and may vary among individuals and agencies making the observation. The GLFC and cooperating biologists attempt to standardize evaluations as much as possible through workshops and other opportunities to share information.

Interpretation

Increasing trap catches of spawning-run sea lampreys, numbers of streams with larval populations, and overall abundance of larvae in streams may indicate an expanding sea lamprey population. Increasing wounding rates in the presence of stable prey populations indicates an increase in sea lamprey abundance and in the amount of damage to prey populations. Data regarding total mortality in trout and salmon is also needed to properly interpret this indicator, since increasing total mortality in trout and salmon populations reduces the number of older fishes and the reproductive potential of these populations.

Comments

Efforts are underway to improve the precision and accuracy of the measures of sea lamprey abundance and of the damage they inflict on trout and salmon populations in the Great Lakes. Improved measures will allow more precise interpretation of status and trend data and will help determine appropriate control measure responses.

Unfinished Business

- Need a more quantifiable endpoint for Lake Michigan.
- Can an endpoint for wounding rates be developed?

Relevancies

Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): exotics
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised

March 7, 2000

Native Unionid Mussels (Indicator ID: 68)

Measure
Distribution and abundance, reported as number of individuals per unit of sampling effort; soft tissue weight; and reproductive output of the Native Unionid mussel.

Purpose
This indicator will assess the population status of native Unionid populations, and it will be used to infer the impact of the invading Dreissenid mussel on the Unionid mussel.

Ecosystem Objective
The diversity of native invertebrate fauna should be maintained in order to stabilize ecosystem habitats throughout the Great Lakes and their tributaries and connecting channels. In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint
Reestablish diverse, self-sustaining populations of native mussels in all historical habitats in the Great Lakes where they have been extirpated by the zebra mussel. Population characteristics should be equivalent to those in reference populations in these or similar habitats prior to the establishment of zebra mussels or where zebra mussels do not occur.

Features
Native Unionids are the largest and longest-lived invertebrates in the Great Lakes basin and are key players in the movement of organic and inorganic particulate matter between the sediment layer and overlying water column. Native Unionid populations are generally highly vulnerable to extinction by invading Dreissenids. Unionid mortality results both from attachment of Dreissenids to Unionid shells (biofouling) and from food competition with Dreissenids. Mortality can occur within two years of the initial Dreissenid invasion and extinction rate generally varies directly with Dreissenid population density. The type of habitat occupied by the Unionids also strongly influences their risk of extinction. For example, Unionids may be able to escape extinction in soft-bottomed habitats where they can burrow deeply and suffocate Dreissenids that attach to their shells. Unionids may also survive better in free-flowing streams than in streams with dams. In streams with dams, Dreissenids are most abundant in impoundments and tailrace areas. In free-flowing stream reaches and in streams without dams, Dreissenid populations rarely reach densities high enough to adversely affect Unionid populations.

Illustration
This indicator will be presented as a map showing population locations and population metrics throughout the Great Lakes basin.

Limitations
There is very little historical data on the distribution and abundance of Unionids in the Great Lakes basin and the available information (mainly from inland surveys conducted in the 1930s-1950s) is not quantitative. The highly clumped distributions typical of most Unionid populations makes sampling and population estimates problematic, and the difficulty in locating young animals impedes assessment of reproductive output.

Interpretation
Distribution and abundance of each Unionid species, reported as number of individuals per unit of sampling effort, provide a simple and direct measure of population status. Because Unionids tend to have clustered distributions, stratified, quadrat-timed searches or extinction search patterns performed by SCUBA divers offer the most promise for developing good population estimates. Soft tissue weight of individuals can be used as a measure of individual and population health. Tissue dry weight varies with season and reproductive status, but simple regressions comparing body weight to shell length can reliably reflect population health under each of these conditions. Individuals are considered at risk when tissue weight is less than 10% of the total (shell plus tissue) weight. Reproductive output can also be used as a measure of population health. Quantitative estimates of reproductive output are difficult to develop because young Unionids are traditionally very difficult to locate even in good habitat. However, the simple presence of young Unionids seems to be a reliable indicator of a healthy, reproducing population.

Additional data including total organic particulate matter in the water column and data about Dreissenid mussel populations are needed to interpret this indicator. Sites without Dreissenid mussels, with >12 species of Unionids, and with young Unionids present would be considered healthy sites where Dreissenids were having negligible impact. Sites where the Unionids are biofouled and the weight of attached zebra mussels is equal to or greater than the weight of the Unionid are sites where the Unionids can be expected to become extirpated shortly. Sites where total organic particulate matter in the water column averages less than 2 mg/L are sites where food resources are too limited to support remaining Unionid populations.

Comments
The first step is to document where Unionids are located and what species are present. The second step is to determine if young Unionids of any species are present at a site. Secondary sampling efforts can focus on species of concern. The number of Unionid species at a given site in the Great Lakes basin varied widely. Most Unionid communities historically supported >12

species, depending on locality. Lake Huron probably never had more than 6-7 species, but Lake Erie and the connecting channels had 16-18, and the Unionid communities in inland waters in Michigan typically had about 16 species.

The northern riffleshell mussel, which occurred in Great Lakes connecting channels and perhaps in western Lake Erie, is listed by the U.S. government as "threatened" and action is being taken to change that listing to "endangered". That species is state-listed as "endangered". The Dreissenid mussel has probably exterminated northern riffleshell mussel populations in the connecting channels.

The species diversity and density of Unionids has severely declined in Lake Erie, the Detroit River, and Lake St. Clair since the arrival of Dreissenid mussels there in the mid-1980s. Species diversity of Unionids there has dropped from an average of 16 to less than 1. Many sites that historically supported Unionids now contain no live Unionids and no young (<5 years of age) have been found at these sites since about 1989.

Unfinished Business

- Although there may not be an endpoint for population, as well as reproductive output, can an endpoint be provided for soft tissue weight? Can any goal for population and reproductive output be stated?

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics
SOLEC Grouping(s): **open waters, nearshore waters**, coastal wetlands
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised

March 8 , 2000

Lake Trout and Scud (*Diporeia hoyi*) (Indicator ID: 93)

Measure

Abundance, yield, or biomass, and self-sustainability of lake trout and scud (*D. hoyi*) in coldwater, oligotrophic habitats of the Great Lakes.

Purpose

This indicator will show the status and trends in lake trout and scud populations, and it will be used to infer the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

Ecosystem Objective

"Lake Superior should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a coldwater community and the [*Diporeia*] hoyi as a key organism in the food chain" (GLWQA). Lake trout are also historically important top predators in the other Great Lakes and should be maintained in accordance with the lake-specific Fish Community Goals and Objectives. Relates to Annexes 1 and 2 of the GLWQA.

Endpoint

In Lake Superior, lake trout stocks should be self-sustaining with a productivity >0.38 kg/ha/y; *Diporeia hoyi* should be maintained throughout the lake at abundances of 220-320/m^2 at depths <100m and 30-160/m^2 at depths >100m (GLWQA).

Self-sustainability and appropriate lake-specific quantitative measures of abundance, yield, or biomass should be established as reference values in the other lakes. The reference values can perhaps be based on target values provided in the FCGO for each lake:
Lake Superior (1990): *Achieve a sustained annual yield of 4 million pounds of lake trout from naturally reproducing stocks. . .*
Lake Huron (1995): *Establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species. . .*
Lake Michigan (1995): *Establish a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout. Establish self-sustaining lake trout populations.*
Lake Erie (1999 draft): *Manage the eastern basin ecosystem to provide sustainable harvests of valued fish species, including . . . lake trout. . . Continue efforts to restore a self-sustaining population of lake trout to the modest levels of abundance observed historically. . .*
Lake Ontario (1999): *Achievement of rehabilitation measures for lake trout (Schneider et al. 1998).*

The lake trout is a highly valued species that is usually heavily exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

Features

Self-sustainability of lake trout is measured in lakewide assessment programs carried out annually in each lake. The historical dominance of lake trout in oligotrophic waters in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production and reestablishing self-sustaining populations of lake trout throughout their native range in the basin will help ensure dominance of these two species in the ecosystem and the maintenance of a desirable aquatic community in oligotrophic, coldwater habitats. The desired trend is increasing dominance of the indicator species to historical levels in coldwater, oligotrophic habitats throughout the basin.

Illustration

For each lake, a graph with lake trout and scud metrics on the x-axis and year on the y-axis will be presented.

Limitations

The indicator is of greatest value in assessing ecosystem health in the oligotrophic, open-water portions of Lake Superior; it may be less useful in nearshore areas of the lake and the quantitative reference values for Lake Superior may not apply closely to oligotrophic areas of the other lakes. Target reference values for scud abundance have not been developed for all five lakes. Because the indicator includes only two species, it may not reliably diagnose causes of degraded ecosystem health. A number of lakewide surveys and assessments of benthic invertebrates communities, including scud, have been made over the past several decades in the Great Lakes. The current status of scud populations is generally known, and an understanding of the changes related to the Dreissenid mussel invasion is emerging.

Interpretation

Interpretation is direct and simple. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. However, the availability, or lack thereof, of appropriate lake trout strains may contribute to difficulties encountered in attempts to rehabilitate lake trout and further complicates the interpretation of "healthy" ecosystem function. Causative agents of impairment are not addressed by the indicator.

Comments

Most stocked lake trout are tagged or marked so that the performance of different strains being tested can be evaluated. Unmarked lake trout that are captured are examined in various ways to determine if they were produced by natural spawning. When the number of naturally spawned fish in the lake is judged to be sufficient to meet abundance or production or yield goals outlined above or in Fish Community Goals and Objectives (FCGO) for lake trout, the population in the lake is judged to be self-sustaining. The lake trout populations in Lake Superior have recently been declared recovered and self-sustaining. Lake trout are reproducing successfully in portions of Lake Huron and Ontario, but the number of young produced annually and surviving to reproductive age is not yet sufficient to support numerical population goals established in the FCGO for lake trout in these lakes. Lake trout abundance, yield, or biomass reference values are now generally met throughout the lower four Great Lakes by stocking lake trout.

Schneider, C.P., T. Schaner, S. Orsatti, S. Lary, and D. Busch. 1998. A management strategy for Lake Ontario lake trout. Great Lakes Fish. Comm. 23 p.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

Last Revised

March 13, 2000

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Nearshore Fish

(Indicator ID: 101)

Measure
Frequency of tumors and other related anomalies in nearshore fish.

Purpose
This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in nearshore fish, and it will be used to infer areas of degraded habitat within the Great Lakes.

Ecosystem Objective
To restore and protect beneficial uses in Areas of Concern or in open lake waters, including beneficial use (iv) *Fish tumors or other deformities* (GLWQA, Annex 2). This indicator also supports Annex 12 of the GLWQA.

Endpoint
When the incidence rate of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers. (IJC Delisting criteria, see IJC 1996)

Features
Epizootics (sudden outbreaks) or elevated frequencies of tumors (neoplasms, including cancer) have become more frequent in the past three decades and have gained profile as indicators of beneficial use impairment of Great Lakes aquatic habitat and also as "early warnings" of potential impact on humans. Some tumors are genetically induced, others are virally induced, and a third group is considered to be chemically induced. There is a substantial body of evidence from field and laboratory studies showing that chemical carcinogens can cause tumors of the type included in this third group. These tumors typically affect the liver. External deformities other than external tumors, must be carefully evaluated if they are used to assess beneficial use impairment. The DELT anomaly index provides a tool for assessing the impact of such deformities.

A decline in PAH in river sediment in a Great Lakes tributary was accompanied with a decline in liver tumors in brown bullhead, suggesting restoration of Great Lakes aquatic habitats polluted with chemical carcinogens may be possible.

This indicator is similar to 4503, but applied to nearshore fish species rather than to coastal wetland species.

Illustration
For each lake, a graph will be presented showing the DELT metric in a species or local population over time. The x-axis will show years and the y-axis will show the DELT metric.

Limitations
The indicator is most useful in defining habitats that are heavily polluted and largely occupied by pollution tolerant fishes. Joint U.S.-Canada studies of benthic fishes in a gradient of polluted to pristine Great Lakes habitats using standardized methodology would greatly enhance our knowledge of the causes of tumors and their usefulness as indicators of ecosystem health.

Interpretation
Tumor production is generally believed to be a response to a degraded habitat and toxic exposure to carcinogens, but may also be due to viral and bacterial agents. Incidences of tumor prevalence should be cross-correlated with location to determine trends. Impairment determinations will be based on a comparison of rates of occurrence of fish tumors or related anomalies at sites of interest with rates at unimpacted or least-impacted (reference) sites. Impairment occurs when:

1. An intestinal or liver tumor prevalence of >5% (rate at reference site exceeded by >5%) occurs in common native nearshore species of benthic dwelling fishes (e.g., brown bullhead, black bullhead, white sucker, and several species of redhorse). Tumors are neoplasms of intestinal, bile duct, or liver cells, as determined by histopathology.

2. A prevalence of lip tumors >10%, or of overall external tumors >15% in any of the benthic species listed in 1 above. Tumors are papillomas or other neoplasms, as determined by histopathology.

3. A DELT (deformities, eroded fins, lesions, and tumors) Index (Ohio EPA) of > 0.5%. The fish species used in compiling the index is not limited to the species listed in 1 above.

Comments
This indicator was prepared using information from:

Edsall, T., and M. Charlton. 1997. Nearshore waters of the Great Lakes. State of the Lakes Ecosystem Conference '96 Background Paper. ISBN 0-662-26031-7.

IJC. 1996. Indicators to evaluate progress under the Great Lakes Water Quality Agreement. Indicators for Evaluation Task Force. ISBN 1-895058-85-3.

Unfinished Business

- A discussion of the potential limitations associated with this indicator (e.g., data collection, cost, etc.) Needs to be included.
- On what basis can the subjective tags of "good" and "poor" be applied towards progress of the Beneficial Use Impairment.

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 4: Fish tumors and other deformities

Last Revised

March 8, 2000

Benthos Diversity and Abundance (Indicator ID: 104)

Measure
Species diversity and abundance in the aquatic oligochaete community.

Purpose
This indicator will assess species diversity and abundance in the aquatic oligochaete community, and it will be used to infer the relative health of the benthic community.

Ecosystem Objective
This indicator addresses the general FCGO to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. This indicator supports Annex 2 of the GLWQA.

Endpoint
Appropriate quantitative measures of species abundance and diversity should be established as reference values for a healthy, diverse benthic community.

Features
Aquatic oligochaete community has been used as one index to assess the relative health of the benthic community. Oligochaetes are widespread and their abundances vary directly with the degree of organic enrichment. In addition, oligochaete species differ in their tolerances to polluted conditions; as organic enrichment declines, species composition shifts from pollution-tolerant to pollution-sensitive species. The desired trend is toward a diverse oligochaete community with inclusion of pollution-sensitive species.

Illustration
For each lake, a graph showing the species composition and abundance of the oligochaete community on the y-axis and years on the x-axis will be presented to illustrate the changes in species metrics over time. A map will be used to show the major, within-lake, spatio-temporal differences.

Limitations
Identifying oligochaete taxonomy is a highly specialized and time consuming activity that requires training and experience. Also, historical data is not housed in a data base and an endpoint for this indicator has not been established.

Interpretation
Abundant, pollution-tolerant oligochaete species indicate degraded habitats. Increasing species diversity and decreasing abundance of oligochaetes indicate return to healthy habitats.

Comments
This indicator covers benthic areas in which other indicators (Hexagenia and Diporeia) may be absent. Water depth has a strong effect on benthic community composition and should be standardized in any sampling design. Studies of benthic communities in Lake Erie, the Bay of Quinte, and the Detroit and St. Clair Rivers conducted in the early 1980s found changes in community structure of oligochaetes. In areas of western Lake Erie nearest major river mouths, and in the Bay of Quinte, a significant decline in oligochaete numbers suggests that a decline in organic enrichment occurred over the period. Near Cleveland Harbor, there was an increase in number of taxa, a reduction in the proportion of oligochaetes, and widespread distribution of pollution-sensitive forms not observed in the 1970s.

Unfinished Business
- May want to consider identifying specific species of interest to measure.
- Need to quantify "abundant" and "diverse".
- What will be the baseline to determine if species diversity is increasing or decreasing?

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, habitat
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised
March 8, 2000

Phytoplankton Populations (Indicator ID: 109)

Measure

Phytoplankton biomass (species and size composition) and size-fractionated primary productivity (Carbon-14 uptake or photosynthesis) as indicator of microbial food-web structure and function.

Purpose

This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes, and it will be used to infer the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Ecosystem Objective

Mesotrophic to oligotrophic conditions are needed to maintain healthy food-web dynamics and habitat integrity of the Great Lakes ecosystem. Goals of phosphorus control are to maintain an oligotrophic state and relative algal biomass of Lakes Superior, Huron and Michigan, and to maintain algal biomass below that of a nuisance condition in Lakes Erie and Ontario (GLWQA Annex 3). This indicator also supports Annex 2 of the GLWQA.

Endpoint

An endpoint needs to be established, based on an international literature search of current and historical data of temperate ecosystems to determine a range of biomass concentrations, species and size structure, as well as fractionated primary productivity (Carbon-14 uptake) for various size fractions as being indicative of healthy and mesotrophic to oligotrophic trophic status.

Features

It is well known that the phytoplankton population and its productivity changes with anthropogenic pollution, both nutrients and contaminants. The ecosystem changes are reflected by the change of phytoplankton composition and productivity. For example, Lake Superior represents a pristine, healthy and ultra-oligotrophic ecosystem harboring a unique collection of phytoplankton species. Similarly, it is common knowledge that Lake Erie's phytoplankton composition, which was once eutrophic, has dramatically changed to meso-oligotrophic status due to phosphorous abatement and the invasion of zebra mussels. A great deal of data are available globally (temperate region) and in the Great Lakes about phytoplankton biomass, composition and primary productivity which will reflect the overall ecosystem health including grazing pressures of the exotic predators.

Illustration

A table with list of species or a diagram can be given as an illustration.

Limitations

Phytoplankton taxonomy (microscopic identification and enumeration) is a highly specialized and time consuming activity that requires intensive training and experience which is generally lacking in the Great Lakes. However, if properly done the phytoplankton analysis generates scientific, precise, and reliable species data that reflects the sensitivity of phytoplankton to anthropogenic stressors.

Interpretation

Comments

The study of lower trophic levels and their use as indicators have been largely ignored in the Great Lakes. There is an immediate need to evaluate the microbial loop - the base of the food chain ranging from bacteria, heterotrophic nanoflagellates, autotrophic picoplankton, ciliates to phytoplankton (nanoplankton and microplankton-netplankton).

This indicator was prepared using information from:
M. Munawar, I.F. Munawar, P. Ross & R. Dermott. 1992. Exploring aquatic ecosystem health: A multi-trophic and an ecosystemic approach. J. Aquat. Ecosyst. Health. 1:237-252

M. Munawar, I.F. Munawar, L.R. Culp and G. Dupuis. 1978. Relative importance of nannoplankton in Lake Superior phytoplankton biomass and community metabolism. J. Great Lakes Research. 4:462-480

Unfinished Business

- An endpoint needs to be established.
- The method of graphically displaying this indicator needs to be determined.
- Additional information is needed to interpret the data as well as a range of "good" or "poor" (e.g., an oligotrophic ecosystem that harbors phytoplankton populations that are diverse in species and size would indicate a healthy ecosystem.)

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, exotics
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of Phosphorus, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

Last Revised

March 8, 2000

Phosphorus Concentrations and Loadings (Indicator ID: 111)

Measure

Total phosphorus levels (ug/L) in the springtime open waters, and annual total phosphorus loads to each lake.

Purpose

This indicator will assess the total phosphorus levels and loadings in the Great Lakes and it will be used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

Ecosystem Objective

Goals of phosphorus control are to maintain an oligotrophic state and relative algal biomass of Lakes Superior, Huron and Michigan, to maintain algal biomass below that of a nuisance condition in Lakes Erie and Ontario, and to eliminate algal nuisance in bays and in other areas wherever they occur (GLWQA Annex 3). The IJC developed the following delisting guideline for eutrophication or undesirable algae: 'no persistent water quality problems (e.g., dissolved oxygen, depletion of bottom waters, nuisance algal blooms or accumulations, and decreased water clarity) attributed to cultural eutrophication.'

The indicator also supports Annexes 1, 2 and 13 of the GLWQA.

Endpoint

Maximum annual phosphorus loadings to the Great Lakes that would allow achievement of the stated goals (above) are: Lake Superior - 3400 tonnes, Lake Huron (main lake) - 2800 tonnes, Lake Michigan - 5600 tonnes, Lake Erie - 11,000 tonnes, Lake Ontario - 7000 tonnes (GLWQA, Annex 3). If these loading rates are maintained, the expected concentration of total phosphorus in the open waters of each lake are: Lake Superior - 5 ug/l, Lake Huron - 5 ug/l, Lake Michigan - 7 ug/l, Lake Erie Western Basin - 15 ug/l, Lake Erie Central Basin - 10 ug/l, Lake Erie Eastern Basin - 10 ug/l, Lake Ontario - 10 ug/l (IJC 1980).

Features

Analysis of phosphorus concentrations to the Great Lakes is ongoing and reliable, but insufficient monitoring of tributaries has been undertaken since 1993 to calculate reliable loading estimates. Current methodology used for analysis is adequate. This indicator provides information to infer the baseline potential productivity of each lake and linkages to future biological problems related to a potential return to excess nutrient loads. Also, the filtering effects of new colonizing species – zebra and quagga mussels – appear to exacerbate the effects of declining phosphorus loading (hence declining lake productivity). Measurements and reporting must reliably reflect spatio-temporal differences on scales needed to effectively address the ecosystem objective. Particular emphasis should be placed on open-lake data collected in the spring of the year, and comparison should be made with the GLWQA objectives. Biannual survey data are available for 1982 to present.

Illustration

For each lake, a graph will be presented showing total phosphorus concentrations and loadings on the y-axis and years on the x-axis. A map will be presented showing major, within-lake, spatio-temporal distributions of phosphorus concentrations.

Limitations

Tributary monitoring is currently (2000) insufficient to evaluate loadings of phosphorus.

A research effort should be undertaken to understand the effects of zebra mussels on phosphorus dynamics in the Great Lakes, and to then incorporate those effects into existing water quality models. The revised models should then be used to reanalyze the relationships between annual phosphorus loadings, the expected resultant phosphorus concentrations in the open waters, and the potential for nuisance growths of algae.

Interpretation

Desirable outcomes are the absence of blooms of undesirable algae and total phosphorus concentrations and loadings that do not exceed the target levels specified in the GLWQA. Remote sensing and satellite imagery can be used to identify algae blooms, which may then be correlated to phosphorus concentrations or increased loadings.

Comments

This indicator was prepared using information in:

Edsall, T., and M. Charleton. 1997. Nearshore waters of the Great Lakes. State of the Lakes Ecosystem Conference '96 Background Paper. ISBN 0-662-26031-7.

Charleton, M., and R. LeSage. 1999. Lake Erie in Transition: the 1990s. In State of Lake Erie (SOLE). M. Munawar, T. Edsall, and I. F. Munawar (eds.) Backhuys Publishers, Leiden, The Netherlands (In Press).

IJC. 1980. Phosphorus Management for the Great Lakes. Final report of the Phosphorus Management Strategies Task Force to the IJC Great Lakes Water Quality Board and Great Lakes Science Advisory Board.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): nutrients
SOLEC Grouping(s): **open waters, nearshore waters**, coastal wetlands
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus
GLFC Objective(s): Erie
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 9: Restrictions on drinking water consumption or taste and odour problems, 11: Degradation of aesthetics, 13: Degradation of phyto/zooplankton populations

Last Revised

March 8, 2000

Contaminants in Young-of-the-Year Spottail Shiners

(Indicator ID: 114)

Measure

Concentration of PBT chemicals in young-of-the-year spottail shiners.

Purpose

This indicator will assess the levels of PBT chemicals in young-of-the-year spottail shiners, and it will be used to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

Ecosystem Objective

Forage fish concentrations of PBT chemicals should not pose risk to fish-eating wildlife. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint

Features

This indicator will be used to monitor long-term fluctuations in the concentration of measured contaminants and the risk they pose to fish-eating wildlife. Shiner collections have been ongoing for almost two decades and represent one of the best long-term data bases on chemicals in the Great Lakes. Because young-of-the-year spottail shiners are small and stay close to their natal area, their chemical concentrations provide information on local chemical inventories as well as the variability and distribution of the chemicals throughout the lakes. The shiners are captured from several spots on each Lake; therefore, the data can be used to illustrate both variability and average levels of PBT chemical exposure to fish-eating wildlife throughout the lakes

Illustration

Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space. As decline of chemicals is an exponential decline, these graphs will be depicted on an logarithmic Y axis versus time.

Limitations

Trends of chemical contaminants in spottail shiners are confounded by other factors including: food chain effects, potential weather effects, analytical and sampling variability. These factors limit the usefulness of the shiner data as an indicator of short-term trends of PBTs in the Great Lakes. Larger, older forage fish may have higher PBT concentrations than young-of-the year spottail shiners, and therefore, shiner data may underestimate risk to fish-eating wildlife.

Interpretation

Comments

Concentrations of contaminants in young-of-the-year spottail shiners represent a good indicator of local concentrations of chemicals and potential risk to fish-eating wildlife.

Unfinished Business

- Need to provide the names of the PBT chemicals will be measured by this indicator.
- Need to provide a reference for the ecosystem objective.
- An endpoint, or frame of reference in which to interpret the data, needs to be defined.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 23, 2000

Contaminants in Colonial Nesting Waterbirds (Indicator ID: 115)

Measure

1) Annual concentrations of DDT complex, PCBs/PCDFs/PCDDs and other organic contaminants and Hg and other metals in Herring Gull eggs from 15 sites from throughout the Great Lakes (U.S. and Canada).
2) Periodic measurement of biological features of gulls and other colonial waterbirds known to be directly or indirectly impacted by contaminants and other stressors. These include (but are not limited to): clutch size, eggshell thickness, hatching and fledging success, size and trends in breeding population, various physiological biomarkers including vitamin A, immune and thyroid function, stress hormone levels, liver enzyme induction, PAH levels in bile and porphyrins and genetic and chromsomal abnormalities.

Purpose

This indicator will assess chemical concentration levels in a representative colonial waterbird, and it will be used to infer the impact of these contaminants on colonial waterbird physiology and population characteristics.

Ecosystem Objective

This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint

Chemical levels and biological measures in colonial nesting waterbirds are not different from those from reference sites in Atlantic Canada or from the Prairies.

Features

Although there are Great Lakes wildlife species that are more sensitive to contaminants than Herring Gulls, and colonial nesting waterbird species in general, there is no other species which has the historical dataset that the Herring Gull does. As contaminant levels continue to decline (if they do), the usefulness of the Herring Gull as a biological indicator species may lessen (due to its reduced sensitivity to low levels of contamination) but its value as a chemical indicator will remain and probably increase - as levels become harder and harder to measure in other media. As well, it is an excellent accumulator. Adult Herring Gulls nest on all the Great Lakes and the connecting channels and remain on the Great Lakes year-round. Because their diet is usually made up primarily of fish, they are an excellent terrestrially nesting indicator of the aquatic community. Historical data on levels of chemical contamination in gull eggs are available, on an annual basis, for most sites in both the Canadian and U.S. Great Lakes dating back to the early 1970s. An immense database of chemical levels and biological measures from the Great Lakes, as well as many off-Lakes sites, is available from CWS. For Herring Gulls, many of the above biological measures are correlated with contaminant levels in their eggs. In other colonial waterbirds there are similar correlations between contaminant levels in eggs and various biological measures. Contaminant levels in eggs of other colonial waterbirds are usually correlated with those in Herring Gulls.

Illustration

1) Temporal trends, portrayed as annual contaminant levels over time, for 1974-present in most instances, are available for each site and each compound, for example, DDE, 1974-1997, for Toronto Harbour and could be displayed graphically. 2) Geographical patterns in contaminant levels, showing all sites relative to one another, are available for most years 1974-present and for most compounds, for example, PCBs, 1997, at 15 Great Lakes sites from Lake Superior to the St. Lawrence River (including U.S. sites) and could be displayed on both maps and graphs.

Limitations

Herring Gulls are highly tolerant of persistent contamination and may underestimate biological effects occurring in other less monitored, more sensitive species. Also, some adult Herring Gulls from the upper Lakes, especially Lake Superior, move to the lower Lakes, especially Lake Michigan, during harsh winters. This has the potential to confound the contaminant profile of a bird from the upper Lakes. Most of the gull's time is still spent on its home lake and this has not been noted as a serious limitation up to this point. Using contaminant accumulation by young, flightless gulls would eliminate this problem but their contaminant levels and effects would be less due to the much reduced contaminant exposure/intake.

Interpretation

Other tissues and species analyzed as necessary to confirm findings in Herring Gulls.

Comments

Contaminant concentrations in most colonial-nesting, fish-eating birds are at levels where gross ecological effects, such as eggshell thinning, reduced hatching and fledging success, and population declines, are no longer apparent. Greater reliance for detecting biological effects of contaminants is being put upon physiological and genetic biomarkers. These are not as well characterized, nor are they understood as easily by the public. Other complementary species include: Double-crested Cormorant (Phalacrocorax auritus), Common Tern (Sterna hirundo), Caspian Tern (Sterna caspia) and Black-crowned Night-Heron (Nycticorax nycticorax). The Herring Gull egg contaminants dataset is the longest running continuous contaminants dataset for wildlife in the world.

1) Chemical levels and trends: Contaminant levels in almost all Great Lakes colonial waterbirds are significantly and substantially reduced from what they were 25 years ago. However, now, in the 1990s, year to year differences in contaminant levels are quite small and without statistical analysis it is often difficult to tell if a compound has stabilized" and is undergoing only year to year, non-significant, fluctuations or if it is still declining. Our analyses show that most contaminants at most sites are continuing to decline at a rate similar to what they have over the last decade or two. However, some compounds, at some sites, have stabilized. Geographical differences for a given compound among sites on the Great Lakes are not as dramatic as they once were. There is greater similarity in contaminant concentration among Great Lakes sites now than there was in the past. However, differences in contaminant levels between sites on and off the Great Lakes are still fairly evident.

2) It is difficult to show consistent differences in biological effects among colony sites within the Great Lakes. This is probably due to the great overall reduction in contaminant levels as well as the lessening in differences among Great Lakes sites. The comparisons which show the greatest differences for biological effects of contaminants are between sites on and off the Great Lakes.

Unfinished Business

- Need to an ecosystem objective that this indicator addresses and provide a reference.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Erie
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised

Feb. 23, 2000

Zooplankton Populations (Indicator ID: 116)

Measure
1) Community Composition; 2) Mean Individual Size; and 3) Biomass and Production.

Purpose
This indicator will assess characteristics of the zooplankton community, and it will be used to infer over time changes in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

Ecosystem Objective
Maintain the biological integrity of the Great Lakes and to support a healthy and diverse fishery as outlined by the Goals and Objectives of the LaMPs and Great Lakes Fishery Commission. This indicator supports Annex 2 of the GLWQA.

Endpoint
For mean individual size, Mills et al. (1987) suggest 0.8 mm as an optimal size when the water column is sampled with a 153-μm mesh net. Endpoints for community composition and biomass and productivity depend on the desired trophic state and type of fish community. Zooplankton as indicators of plankton and ecosystem community health are still in the early stages of development. Some information on the variability in zooplankton mean length is presented in Mills et al. (1987), and Johannsson et al. (1999b,c). Empirical relationships can be found in the literature relating zooplankton biomass and production to other state variables, such as total phosphorus, chlorophyll a concentration, primary production and zooplankton mean length (Makarewicz and Likens 1979 (if rotifers are measured), (McCauley et al. 1980), Hanson and Peters 1984, Yan 1985, McQueen et al. 1986, Johannsson et al. 1999a). End points for community structure are not clear now that new exotic zooplankton (Bythotrephes and Cercopagus) have entered the lakes.

Features
This indicator tracks trends in zooplankton populations, including community composition, mean individual size, and biomass and production, over time. Some data are available for Lake Ontario from 1967, 1970, 1972 on composition and abundance. Composition, density, biomass and production data are available for 1981-1995 from the DFO Lake Ontario Long-Term Biological Monitoring (Bioindex) Program (Johannsson et al. 1998). Mean individual size was not measured for the community during these years, but could be obtained from archived samples. Zooplankton work on Lake Erie has been reviewed by Johannsson et al. (1999c).

Illustration
Zooplankton mean length, ratio of calanoids to cladocerans + cyclopoids and biomass can be presented as line graphs if trend data is available. Shifts in composition might be better tracked using factor analysis followed by multi-dimensional scaling to show how the community structure moves in a two-dimensional space.

Limitations
At this point, it is not possible to rate mean individual size of zooplankton if they do not equal 0.8 mm. It is unclear how different energy flow is if the mean size is 0.6 mm or 1.0 mm, and if 0.6 mm is equivalent to 1.0 mm.

Interpretation
Some of the other measures which would help with the interpretation of the zooplankton data would include, total phosphorus, chlorophyll a, temperature, oxygen (in some regions), and if possible primary production and phytoplankton composition and biomass.

Comments
Composition: Changes in composition indicate changes in food-web dynamics due to changes in vertebrate or invertebrate predation, and changes in system productivity. Ratios such as calanoids to cladocerans + cyclopoids have been used to track changes in trophy. This particular ratio may NOT work in dreissenid systems (Johannsson et al. 1999c).

Mean Individual Size: The mean individual size of the zooplankton indicates the type and intensity of predation. When the ratio of piscivores to planktivores is approximately 0.2, the mean size of the zooplankton is near 0.8 mm. These conditions are characteristic of a balanced fish community (Mills et al. 1987). There is a high degree of variability about this relationship and further work needs to be done to strengthen this indicator. Total biomass and possibly production decrease with decreases in the mean size of the zooplankton (Johannsson et al. 1999b).

Biomass and Productivity: Biomass can be used to calculate production using size and temperature dependent P/B ratios for each of the major zooplankton groups. Production is a much better indicator of energy transfer within a system than abundance or biomass.

Of these measures, composition and mean size are the most important. However, these factors provide the information needed to calculate biomass and production.

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Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, exotics
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

Last Revised

Feb. 23, 2000

Atmospheric Deposition of Toxic Chemicals (Indicator ID: 117)

Measure
Annual average loadings of toxic chemicals from the atmosphere to the Great Lakes, based on measured atmospheric concentrations of the chemicals, as well as wet and dry deposition rates.

Purpose
This indicator will estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it will be used to infer potential impacts of toxic chemicals from atmospheric deposition on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 2, 12, 15 and 17 of the GLWQA.

Endpoint
When atmospheric concentrations of toxic chemicals associated with existing water quality criteria are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. Loadings will be calculated based on 1) measured atmospheric concentrations of the chemicals and 2) wet and dry deposition rates using techniques described in the "Chemicals of Concern" chapter of the Lake Superior Stage II LaMP. The indicator data will also demonstrate the magnitudes of the trends in the loadings of toxic chemicals from the air to the water. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

Illustration

Limitations
There is concern that some of the features of the loadings calculations (see Comments field) are poorly known at present. The trends in the atmospheric concentrations of toxic chemicals, however, are much better known and a much better indicator of progress towards virtual elimination. Errors in these trends should be clearly stated and tested against the null hypothesis (things are not changing).

Interpretation
Progress will be determined based on whether trends of the toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations)and by the number of chemicals which reach the virtual elimination goal.

To understand the pollutant concentration trends related to atmospheric deposition, additional information is needed in interpreting pollutant load estimates derived using the suggested calculation (see Comments field). For example, information on the yearly variations in the rain rate (dry years versus wet years) is needed to understand the pollutant concentrations associated with wet deposition. Also, since it is known that the pollutant loads associated with atmospheric deposition have seasonality for some components, the data should be statistically deseasonalized to properly determine the trend.

Comments
Estimates of atmospheric deposition have been made since 1988 (Strachan and Eisenreich, 1988; Eisenreich and Strachan, 1992). More recently atmospheric deposition fluxes and loads have been measured by the Integrated Atmospheric Deposition Network (IADN) (Hoff et al., 1996; IADN Steering Committee, 1997). The indicator follows procedures set out in the IADN Quality Assurance Program Plan (1994). Several primary indicators of progress towards virtual elimination are found in the estimation of loading to the lakes, L, where L = W + D + G, below.

Wet deposition (W) is calculated as:

$$W(ng\,m^{-2}y^{-1}) = 1000\,C_p\,R_p$$

where C_p (ng/l) is the volume-weighted mean precipitation concentration averaged over a year period, R_p is the precipitation rate in m y^{-1} (water equivalent for snow), and the factor of 1000 converts litres to cubic metres.

The magnitude of W and its change with time is an indicator of progress towards virtual elimination. It should be noted, however, that yearly variations in the rain rate (dry years versus wet years) will complicate the interpretation of the indicator. Therefore, the concentration of the chemical in precipitation should also be evaluated as an indicator.

Dry deposition of particles is calculated from:

$$D(ng\, m^{-2} y^{-1}) = v_d C_{a,part}$$

where v_d (m y^{-1}) is the dry deposition velocity of the species in question (a function of particle size and hygroscopic nature of the particles) and $C_{a,part}$ (ng m^{-3}) is the particulate phase concentration of the chemical in air. Since the dry deposition velocity of particles is not well known, it has been specified as 0.2 cm s^{-1} in previous work (Strachan and Eisenreich, 1988; Hoff et al. 1996). Since the deposition velocity is not expected to be a determining factor in the long-term trend of dry deposition (particle sizes will not change much with time), the air concentration of chemicals on the particles will be a primary indicator which can be tracked for trends.

Gas exchange is computed from the knowledge of both the gas phase species concentration in air ($C_{a,gas}$, ng m^{-3}) and the concentration of the chemical in water (C_w, ng/l) through the formula:

$$G(ng\, m^{-2} y^{-1}) = k_{oL}\ (C_{a,gas} \frac{RT}{H} - 1000\ C_w)$$

where k_{oL} (m y^{-1}) is the air-water mass transfer coefficient, H is the temperature dependent Henry's Law constant, R is the gas constant and T is the surface water skin temperature (Schwarzenbach et al., 1993). As expressed above if $G>0$ then the lakes are being loaded from the atmosphere and if $G<0$ then the lakes are a source of the chemical to the atmosphere. There is uncertainty (see below) in some of the chemical and physical properties which are part of the gas phase flux. A more precise indicator of trends in this flux are the air and water concentrations of the chemical themselves.

The rate of change of the loading, $L = W + D + G$, is dL/dt. Since it is known that the loads have seasonality for some components, in order to properly determine the trend, the data should be statistically deseasonalized (i.e, using a Rank-Kendall statistic, standard temperature correction, or equivalent).

Even after deasonalizing the trend data, there may be considerable error in the magnitude of the gas phase exchange. In order not to overstate the loading indicator precision, a secondary measure of the indicator will be the sign of the change in L, in the above equation. If the indicator is positive, the trends in the loadings are increasing and the objective is not being approached. If the indicator is negative, the loadings are decreasing and the objective is being approached. It is likely that if the sign of dL/dt is negative, the change in the atmospheric contributions to the tributary loadings is likely to be of the same sign.

A third component of the indicator is the relative rate of change of the loading with time. The more negative this indicator becomes the faster the goal of virtual elimination will be reached.

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Schwarzenbach, R.P., Gschwend, P.M., and D.M. Imboden. 1993. Environmental Organic Chemistry, Wiley Interscience Publishers, New York.

Unfinished Business

- Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

Relevancies

Indicator Type: pressure
Environmental Compartment(s): air, water
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 15: Airborne toxic substances, 17: Research and development
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

March 8, 2000

Toxic Chemical Concentrations in Offshore Waters (Indicator ID: 118)

Measure
The concentration of toxic chemicals in the offshore waters of the Great Lakes.

Purpose
This indicator will assess the concentration of priority toxic chemicals in offshore waters, and it will be used to infer the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 1 and 12 of the GLWQA.

Endpoint
When concentrations of toxic chemicals associated with existing water quality criteria in the offshore waters of the Great Lakes are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals. Monitoring for this indicator will occur during the two year periods between SOLEC. Every two years, water concentrations of zero discharge and lakewide remediation chemicals should be monitored throughout the offshore waters of Lake Superior, for comparison with an appropriate baseline. Sampling should be conducted during spring, isothermal conditions, as maximum concentrations have been reported during this time.

Illustration
Water concentrations of the zero discharge and lakewide remediation chemicals should be presented in a table which provides both the 95th percentile (see Interpretation field) and the appropriate baseline, for comparison. Spatial distribution maps, showing raw concentration data, should also be provided to indicate spatial gradients and to discern any problem areas.

Limitations
Although measurements exist for many priority chemicals in the Great Lakes system, these measurements are not all obtained on a time scale that would allow for significant reinterpretation every two years. As new information is available, and the indicator is updated, trends will become more discernable and progress toward virtual elimination can be assessed. Errors in these trends should be clearly stated and tested against the null hypothesis (i.e., things are not changing).

Interpretation
Pollutant concentrations will be considered positive only if 95-100% of the available data indicate concentration levels below the lake-specific baseline. Progress will be determined based on whether trends of the IJC priority toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations)and by the number of chemicals which reach the virtual elimination goal.

Comments

Unfinished Business
- Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
March 8, 2000

Concentration of Contaminants in Sediment Cores (Indicator ID: 119)

Measure
The concentrations of toxic chemicals in sediment cores at selected sites within the Great Lakes at ten year intervals.

Purpose
This indicator will assess the concentrations of toxic chemicals in sediments, and it will be used to infer potential harm to aquatic ecosystems by contaminated sediments, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. And, GLWQA Annex 14 Objective asks to identify the nature and extent of sediment pollution of the Great Lakes System. This indicator also supports Annexes 2, 7 and 12 of the GLWQA.

Endpoint
When sediment concentrations of toxic chemicals associated with existing water quality criteria are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of the toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

In the nearshore areas and harbours and bays, cores would be collected every 10 years from sites selected for index monitoring. Index sites should include areas where sediment sampling would provide added value to contaminant investigations, for example, sites previously monitored for contaminants in fish. Sites would also be chosen based on sediment type, expected sedimentation rates, and proximity to potential sources. Cores would be sectioned, dated and analyzed for the toxic chemicals.

Certain estuaries, bays, and harbours on the lakes, are designated as Areas of Concern because of past or on-going pollution problems. Sediment contamination in these areas, taken together, represent cumulative impacts to productive habitat areas. In addition, Areas of Concern can serve as contaminant source areas to the rest of the Lakes. Application of the sediment indicator at Areas of Concern is intended to integrate the information gathered by RAP monitoring efforts to give a lakewide picture for these important habitat areas.

Illustration
The sediment concentrations would be depicted using the standard tables and figures showing the change in concentration at different depths. Only the upper segment of the core would be compared to the yardstick or local standard. In addition, a set of maps showing locations and concentrations of sediments in the nearshore areas and a set of maps showing sediment chemical concentrations in the Areas of Concern would serve to illustrate the indicator.

Limitations
An update of this indicator with new data every two years for SOLEC may not be feasible because sediment cores may only be obtained every decade or so. However, the updates of the indicator when new information arise is applicable to past years (i.e., sediment cores will fill in the history for the previous decade). Errors in these trends should be clearly stated and tested against the null hypothesis (i.e., things are not changing).

Interpretation
Progress will be determined based on whether trends of the toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations) and by the number of chemicals which reach the virtual elimination goal.

Comments
Measurements exist for many priority chemicals in the sediments of the Great Lakes system.

The desired outcome of the indicator is that the trends are negative in sign and that the concentrations reach levels which are no longer measurable by current technology.

Unfinished Business

- For the presentation of the indicator "standard tables and figures" should be defined or the text modified to be more descriptive (e.g., Sediment concentrations at each site, by depth, will be displayed on a bar graph. Current detection limits will be clearly marked).

Relevancies

Indicator Type: pressure
Environmental Compartment(s): sediments
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 7: Dredging, 11: Surveillance and monitoring, 12: Persistent toxic substances, 14: Contaminated sediment
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos, 7: Restrictions on dredging activities

Last Revised

March 8, 2000

Contaminant Exchanges Between Media: Air to Water, and Water to Sediment (Indicator ID: 120)

Measure

Estimates of air to water and water to sediment loadings of toxic chemicals using fugacity based approaches of intermedia transport.

Purpose

This indicator will estimate the loadings of priority pollutants to the Great Lakes, and it will be used to infer the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 1, 12, 14, 15 and 17 of the GLWQA.

Endpoint

When concentrations of priority chemicals within the Great Lakes are no longer measurable above naturally-occurring levels by current technology.

Features

This indicator will track whether concentration trends of the toxic chemicals between media are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. It combines the concentration trends in air (from indicator 117), water (from indicator 118), and sediments (from indicator 119) towards an assessment of overall trend in the loadings of these chemicals to the system. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

Illustration

Limitations

Though measurements of concentrations of toxic chemicals exist for all compartments in the Great Lakes system to compute the measures of this indicator, they are not all obtained on a time scale which would allow for significant reinterpretation every two years (e.g., sediment cores may only be obtained every decade or so). However, the updates of the indicator when new information arise is applicable to past years (for example, sediment cores will fill in the history for the previous decade).

There is concern that some of the features of the loadings calculations are poorly known at present (see Comments field). This problem also exists for indicator 117, Atmospheric Deposition of Toxic Chemicals. It is important that the measures of the mass of chemical in air and in water be made at the same time.

Interpretation

Comments

Loadings are computed using techniques described in the "Chemicals of Concern" chapter of the Lake Superior Stage II LaMP. Intramedia transfers are computed using a fugacity based approach developed by Mackay and his co-workers (1992). The loadings approach for air to water is already expressed in a fugacity framework where the fugacity of a chemical in a medium is:

$$f = M/\sum V_i Z_i$$

where V is the medium volume, Z is the fugacity capacity and M is the mass of chemical in the medium (Mackay et al., 1992). The fugacity capacities for air, water and sediments are:

$Z_{air} = 1/RT$ (R= gas constant, T= temperature in Kelvin)

$Z_{water} = 1/H$ (H = Henry's law constant)

$Z_{sediment} = Z_{water}\, \rho_{sediment}\, \Phi_{sediment}\, K_{oc}/1000$

where

$\rho_{sediment}$ = density of the sediment

$\phi_{sediment}$ = mass fraction in organic phase in the sediment

K_{oc} = octanol-carbon partition coefficient = 0.41 K_{ow} (K_{ow} is the octanol water partition coefficient).

These fugacities are used to predict the air/water, water/sediment loadings. For some chemicals, the knowledge of variables such as Z_{water} and K_{oc} or K_{ow} may be limited.

Mackay, D., W.Y. Shiu and K.C. Ma. 1992. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Vol. 1, Lewis Publishers, Boca Raton, Fl.

Unfinished Business

- Need to provide an example of how the data will be presented (e.g., maps that identify sites and loadings of pollutants).
- Need to provide information on the baseline that will be used to determine if trends are positive or negative.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): air, water, sediments
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters, nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 14: Contaminated sediment, 15: Airborne toxic substances, 17: Research and development
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

March 8, 2000

Wastewater Pollution (Indicator ID: 7059)

Measure

Loadings of metals, phosphorus, BOD and organic chemicals that are released by municipal sewage treatment plants and industrial direct dischargers, into water courses in the Great Lakes basin.

Purpose

To assess the loadings of wastewater pollutants discharged into the Great Lakes basin, and to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

Ecosystem Objective

Sustainable development and healthy ecosystems through support for Annexes 1, 2, 3 and 12 of the GLWQA.

Endpoint

High quality wastewater discharges that approach the ambient quality of the 'sink' they are being discharged to (or the source from which they originated) is a desired endpoint that can best be achieved through pollution prevention ad resource conservation.

Features

Pollutant loadings in wastewater represent waste from land use activities that contaminate the Great Lakes. SOLEC '96 Land Use Background paper discusses the levels of wastewater loading to the Great Lakes. This indicator is related to indicator 7056, Water Withdrawal, since the quality of wastewater effluent is generally improved in total loadings when the hydraulic volume of wastewater is reduced.

Illustration

The indicator will be presented as graphs that display loadings over time by jurisdiction, by lake basin and for the overall basin.

Limitations

Although data are largely available, they are not collected on a necessarily comparable fashion for both the U.S. and Canada. Some work is required to ensure that Ontario data is consistent with the U.S. Since much industrial wastewater flows to municipal sewage treatment facilities the efficiency of these in reducing waste can be hidden.

Interpretation

Wastewater treatment is dependant on the quality of incoming wastewater sources, the state of the technology to process the wastewater and other factors such as fugitive leaks that can increase volumes dramatically at certain times and result in deterioration of the quality of wastewater. The number of hours of by-pass at wastewater plants may be added as another measure, although this addresses the state of the treatment infrastructure more than waste reduction itself. A historical reference of loadings will be used as a benchmark for the indicator.

Comments

Unfinished Business

- Need to determine from where in the Great Lakes basin the information will be collected and how frequently.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens, nutrients
SOLEC Grouping(s): **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances, 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication and undesirable algae, 11: degradation of aesthetics

Last Revised

Feb. 23, 2000

Sediment Available for Coastal Nourishment (Indicator ID: 8142)

Note: This indicator is listed as both a Nearshore Waters and Nearshore Terrestrial indicator.

Measure
Streamflow and suspended sediments at the mouth of major tributaries and connecting channels.

Purpose
To assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and to estimate the amount of sediment available for transport to nourish coastal ecosystems.

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

Endpoint
Functioning longshore transport process necessary for healthy coastal ecosystems.

Features
The role of streamflow in sediment transport and nourishment of coastal ecosystems is needed to evaluate and predict the health of the ecosystems. Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be collected every three years. Trends will indicate a change in the amount of sediments available for coastal nourishment. Monitoring of streamflow and sediment load is one of the oldest and most well established programs in both the United States and Canada.

Illustration
Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be depicted as line graphs.

Limitations
Recent dramatic cuts in the Canadian budget may influence this monitoring. An evaluation is needed to prioritize the location of monitoring locations.

Interpretation
Once baseline values are determined, streamflow at the mouths of specified tributaries and concentration of suspended sediments will be tracked.

Comments
Data may be eventually used to help evaluate the impacts of climate change.

Unfinished Business
- Need to provide a unit of measurement to increase specificity.
- Need to determine a quantifiable endpoint.

Relevancies
Indicator Type: state
Environmental Compartment(s): water, sediments
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore waters, nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Coastal Wetland Invertebrate Community Health (Indicator ID: 4501)

Measure
Relative abundance of sensitive taxa (e.g., mayflies, caddisflies), tolerant taxa (e.g., Chironomini as a proportion of total Chironomidae abundance, Isopoda), richness of specific taxa, and functional feeding groups (e.g., herbivores, detritivores, carnivores), working towards the development of an Index of Biotic Integrity (IBI).

Purpose
To assess the diversity of the invertebrate community, especially aquatic insects, and to infer habitat suitability and biological integrity of Great Lakes coastal wetlands.

Ecosystem Objective
Restore and maintain the diversity of the invertebrate community of Great Lakes coastal wetlands. (GLWQA Annexes 2 and 13).

Endpoint
The endpoint for this indicator will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

Features
To restore/maintain the overall biological integrity of Great Lakes coastal wetlands, the various ecological components need to be adequately represented. The invertebrate IBI will offer information on overall diversity of the invertebrate community and trends over time. The IBI is a multi-indicator, developed from a composite of specific parameters, termed "metrics," used to describe the invertebrate community, structure, function, and abundance. The IBI provides a rigorous approach that quantifies the biological condition of the invertebrate community of Great Lakes coastal wetlands based on data from least-impacted sites that are representative of Great Lakes coastal wetlands, referred to as a reference condition.

Metrics used in the IBI to measure invertebrate community diversity will include relative abundance of sensitive and tolerant taxa, richness of specific taxa, and functional feeding groups, primarily of aquatic insects. Metrics will be scored based on how similar they are to the reference condition. The IBI will also provide a narrative characterization that provides a measure of the environmental condition and will be calibrated for regional use. The cost of monitoring for this indicator may be reduced because monitoring would apply only to the selected set of representative wetlands and may be conducted in conjunction with monitoring for other indicators.

Illustration
For representative coastal wetlands, the IBI would be displayed on a map of each Lake or the basin. In addition, the invertebrate IBI score can be plotted based on a given shoreline distance to reflect patterns in Lake quality. Color-coded symbols could be used to reflect site scores for each representative Great Lakes coastal wetland. As sufficient IBI data becomes available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

Limitations
An invertebrate IBI is being developed for coastal wetlands that are directly connected to the Great Lakes, not for those wetlands that are only connected hydrologically via groundwater. Until the IBI is developed and tested for adequacy, the metrics to be used in developing the IBI (e.g., data on functional feeding groups) will be monitored with the intent that the IBI can be calculated in the future using previously collected monitoring data.

Interpretation
This indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands.

Comments
The presence, diversity and abundance of invertebrates tend to correlate with factors such as water depth, vegetation, and sediment type. Because such localized conditions influence the invertebrate community present in each wetland, a sufficient number of representative wetlands will be needed to characterize each lake basin adequately.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised
Feb. 23, 2000

Coastal Wetland Fish Community Health (Indicator ID: 4502)

Measure

An Index of Biotic Integrity (IBI) will be developed based on measures of species richness and abundance, percent exotic species, percent phytophils and other appropriate parameters.

Purpose

To assess the fish community diversity, and to infer habitat suitability for Great Lakes coastal wetland fish communities.

Ecosystem Objective

Restore and maintain the diversity of the fish community of Great Lakes coastal wetlands. (GLWQA Annexes 2 and 13)

Endpoint

An endpoint for this indicator will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

Features

The IBI provides a rigorous approach to quantify the biological condition of fish communities within the Great Lakes. It is based on reference conditions and is developed from a composite of specific measures used to describe fish community, structure, function, individual health, and abundance. Specific parameters, termed "metrics," are scored based on how similar they are to the reference condition. These parameters will include species richness and abundance, percent exotic species, and percent phytophils. The IBI will also provide a narrative characterization that provides a measure of the environmental condition and will be calibrated for regional use.

Illustration

For representative coastal wetlands, the IBI would be displayed on a map of each Lake or the basin. In addition, the IBI score can be plotted based on a given shoreline distance to reflect patterns in Lake quality. Color-coded symbols could be used to reflect site scores for each representative Great Lake coastal wetland. As sufficient IBI data becomes available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

Limitations

Until the IBI is developed and tested for adequacy, the metrics to be used in developing the IBI will be monitored with the intent that the IBI can be calculated in the future using previously collected monitoring data.

Interpretation

This indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands and nearshore aquatic systems.

Comments

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Coastal Wetland Fish (Indicator ID: 4503)

Measure
Numbers and percent of DELT in coastal wetland fish.

Purpose
To assess the combination of deformities, eroded fins, lesions and tumours (DELT index) in fish of Great Lakes coastal wetlands, and to infer ecosystem health of Great Lakes coastal wetlands.

Ecosystem Objective
Restore the health of fish of Great Lakes coastal wetlands. (GLWQA Annexes 2, 12, 13 and 17)

Endpoint
The incidence DELT should be less than 0.1% of site catch to attain reference conditions (Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity and its rational. Illinois Natural History Survey Publication 5).

Features
DELT anomalies reflect the lowest levels of biological integrity. High incidence of DELT is a reflection of degraded conditions. Fish collected from a site would be inspected for gross external presence of DELT. Fish having DELT would be counted and the percentage of DELT anomalies would be composited over all species and individuals in the total catch.

Illustration
For each Lake, a graph will display the percentage of DELT showing annual mean and 95% confidence intervals for total catch. This indicator can be displayed as either a bar chart or box-and-whisker plot.

Limitations
There are almost no additional monitoring costs associated with this indicator. Field crews collecting fish community data would be required to carefully inspect each fish for the presence of DELT anomalies, which will add handling time. The indicator is closely linked to the overall level of contaminants that contribute either additively or synergistically to reduce biological integrity. Presence of DELT does not always necessarily reflect site conditions since some fish species may be mobile. However, the majority of species remain in select areas for portions of the life cycle and will show signs of any effects.

Interpretation
Where DELT exceeds the endpoint of 0.1%, proximity to point source discharges and other contaminant sources can be evaluated as a link to sources.

Comments
This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The Biodiversity Investment Areas paper from SOLEC '98 identifies the ecoreaches from which representative wetlands that adequately characterizes each lake basin will be selected. This indicator may also apply to nearshore aquatic areas.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 4: fish tumors or other deformities

Last Revised
Feb. 23, 2000

Amphibian Diversity and Abundance (Indicator ID: 4504)

Measure

Species composition and relative abundance of calling frogs and toads, based on evening surveys using protocol developed for the Marsh Monitoring Program (MMP) or modification of MMP protocol.

Purpose

To directly measure the species composition and relative abundance of frogs and toads and to indirectly measure the condition of coastal wetland habitat as it relates to the health of this ecologically important component of wetland communities.

Ecosystem Objective

Restore and maintain the diversity of Great Lakes coastal wetland amphibian communities. Breeding populations of amphibian species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annex 13)

Endpoint

An endpoint will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data on amphibian diversity and abundance would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

Features

To restore/maintain the overall biological integrity of Great Lakes coastal wetlands, the various ecological components need to be addressed. This indicator will track trends in Great Lakes coastal wetland amphibian diversity and relative abundance over time.

Illustration

For representative coastal wetlands along each of the Lakes, species richness and measures of abundance could be graphically displayed. As sufficient data become available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

Limitations

This indicator focuses on frogs and toads because they are more readily censused than other amphibians. Other amphibian species, such as salamanders, would not be censused at all. Nonetheless, monitoring results for the species surveyed (i.e., frogs and toads) may provide an indication of habitat suitability for other amphibians dependent on coastal wetlands. The relationships among calling codes recorded during surveys, amphibian chorus size, and local population size need to be studied. This validation work is necessary for extrapolations from call code surveys to population sizes.

Interpretation

Amphibian populations naturally fluctuate over time; therefore, this indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands. Many amphibian species are associated with wetlands for only a portion of their life cycle. Periodically, more rigorous studies may be needed at some sites to relate trends in species occurrence or relative abundance to environmental factors. Adequate upland areas adjacent to coastal wetlands are important to amphibians, and indicators of suitable, adjacent upland areas also need to be considered when assessing amphibian population trends. Species of particular interest are Northern Leopard Frogs and Bullfrogs. Green Frogs seem to be replacing Bullfrogs in many areas, therefore, the ratio of Green Frogs to Bullfrogs should be monitored.

Comments

Properly trained volunteers currently conduct monitoring and all data are subject to the quality assurance program. Additional coastal wetlands could be selected if additional volunteers are available to conduct monitoring. Any additional wetlands would have to be selected based on criteria to be established. Available data on historical and current presence/ abundance of amphibians should be collected to supplement monitoring data. Monitoring programs/protocols other than the MMP exist, such as backyard survey and road-call count, although they do not specifically focus on coastal wetlands.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

Any deformities should be noted and shared with the monitoring program for deformities.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Contaminants in Snapping Turtle Eggs (Indicator ID: 4506)

Measure
Concentrations of organochlorine chemicals and mercury in snapping turtle eggs.

Purpose
To assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs, and to infer the extent of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

Ecosystem Objective
Snapping turtle populations in Great Lakes coastal wetlands and populations observed at a clean inland reference site, such as Algonquin Provincial Park, Ontario, should not exhibit significant differences in concentrations of organochlorine chemicals and mercury, thereby ensuring hatching success and low abnormality rates. (GLWQA Annexes 1, 12 and 13).

Endpoint

a) Mean wet weight concentrations in snapping turtle eggs should not exceed*:

Toxic Equivalents= 158.3 ug/g
Total polychlorinated biphenyl (PCB)= 0.338 ug/g
Total polychlorinated dibenzo dioxins (PCDD)= 1.0 pg/g
Total polychlorinated dibenzo furans (PCDF)= 3.0 pg/g
pp'DDE (metabolite of DDT)= 0.05 ug/g
mirex= 0.0014 ug/g

b) Mean wet weight concentrations in plasma from snapping turtle eggs should not exceed*:

Total PCB= 17.8 ng/g
Total PCDD= 7.0 pg/g
Total PCDF= 4.2 pg/g
pp'DDE= 1.0 ng/g
mirex= 0.4 ng/g

*See "Comments" for information on the derivation of these tentative concentrations for use as endpoints.

Endpoints for mercury have yet to be developed.

Features
Snapping turtles are long-lived, top predators that bioaccumulate contaminants. Their embryonic and sexual development appear to be sensitive to organochlorine chemicals. Given these characteristics, the snapping turtle is useful in monitoring trends in contaminants levels within specific wetlands. Variations in diet among snapping turtle populations can influence the degree of contamination in the population. Where large contaminated carp are the predominant species in the fish community, and a primary source of food, the contaminant exposure in snapping turtles will likely be higher and persist for longer periods. Some snapping turtle populations consume smaller fish in a more diverse fish community where the turnover rate of contaminants is faster in the fish population. Hence, some sites would show more rapid changes in contaminant trends.

Illustration
Mean concentration of organochlorine chemicals and mercury at the uncontaminated reference site (e.g., Algonquin Provincial Park) superimposed over concentrations from representative sites from the Lakes and connecting channels. This would be presented as a bar graph showing sites and concentrations, along with the mean concentration for the reference site as a comparison.

Limitations
This indicator requires labor-intensive sampling (2 weeks in June) and expensive analyses. The monitoring for this indicator focuses only on persistent chemicals, and therefore does not illustrate trends in other types of contaminants that may be present in Great Lakes coastal wetlands.

Interpretation
Contamination levels observed in snapping turtles at reference sites, and other sites throughout the Great Lakes, would provide the context needed to interpret this indicator. Since variation in diet among snapping turtle populations can influence contaminant levels, additional information on fish diversity at the study sites will help to interpret the trends illustrated by this indicator.

Comments

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

The concentrations provided as endpoints for this indicator serve as tentative concentrations which should not be exceeded to ensure that the hatching success and hatchling deformity rates do not significantly exceed those at the examined inland, non-contaminated reference sites.

The mean wet weight concentration in snapping turtle eggs provided as endpoints are concentrations found in eggs from Big Creek Marsh, Lake Erie which showed no significant difference in hatching rates and deformity rates as compared to Lake Sasajewun, Algonquin Provincial Park, an inland lake in Ontario.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb 23, 2000

Wetland-Dependent Bird Diversity and Abundance

(Indicator ID: 4507)

Measure

Species composition and relative abundance of wetland-dependent birds, based on evening surveys using protocol developed for Marsh Monitoring Program (MMP) or modification of the MMP protocol.

Purpose

To assess the wetland bird species composition and relative abundance, and to infer the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

Ecosystem Objective

Restore and maintain the diversity of Great Lakes coastal wetland bird communities. Breeding populations of bird species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annex 2)

Endpoint

An endpoint will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data on the species composition and relative abundance of wetland-dependent birds would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

Features

This indicator will offer information on wetland bird diversity and abundance trends over time. It will provide a temporal measure of Great Lakes coastal wetland bird communities and may be made compatible with the Marsh Monitoring Program, an ongoing wetland monitoring program initiated throughout the Great Lakes basin in 1995.

Illustration

For representative coastal wetlands along each of the Lakes, trends in relative abundance for individual species could be graphically displayed. Indices, tables and diagrams will be used to depict community species composition characteristics.

Limitations

A rigorously tested index of the relationships between wetland bird community composition and critical environmental factors (i.e. an Index of Biotic Integrity (IBI) for birds) is the preferable approach to community-based indicators, but has not yet been developed for wetland birds. The development of such an IBI should be an important priority. The IBI should be able to take advantage of the information on species occurrence and relative abundance currently collected through the MMP.

Interpretation

Both regional and local populations naturally fluctuate over time, therefore, several years of monitoring data will be required to detect all but the most dramatic trends. Interpretation of this indicator will be most effective if coupled with patterns observed in other indicators (e.g., indicator 4501, Invertebrate Community Health; indicator 4510, Wetland Area by Type).

Wetland birds are highly mobile and most are dependent on wetlands for only portions of their life cycle. Temporal trends in local bird populations can be influenced by factors external to wetlands on the wintering grounds, during migration, or on the breeding grounds. For this reason, intensive work will be required to identify site- and region-specific impacts to bird breeding productivity and survivorship. These intensive studies are particularly important in the absence of a well-tested IBI.

Comments

With proper training and quality assurance, volunteers could conduct wetland bird surveys, allowing a relatively modest investment in SOLEC monitoring and analysis. This indicator would apply most directly to the selected representative wetland sites, but could be made to complement, and draw a regional context from, existing wetland monitoring efforts in both coastal and inland sites in the Great Lakes basin. Wetland birds are important from both a cultural and ecological perspective. Monitoring of wetland-dependent bird species of conservation concern (e.g. Black Tern, Least Bittern, King Rail) should receive special attention during protocol development.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Coastal Wetland Area by Type (Indicator ID: 4510)

Measure
Areal extent of coastal wetlands by type as a range (e.g., dry year/low water level area versus wet year/ high water level area).

Purpose
To assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural variations.

Ecosystem Objective
Reverse the trend toward loss of Great Lakes coastal wetlands, ensuring adequate representation of wetland types across their historical range. (GLWQA Annexes 2 and 13)

Endpoint
No net loss of coastal wetlands due to human actions and, in the future, a net gain to coastal wetlands due to restoration activities, recognizing that a reference year needs to be selected.

Features
The wetland area should be reported as a basin total and by type (based on geomorphology, vegetation, water regime, size class, degradation), putting the baseline numbers into a historical perspective. Monitoring of each specific wetland type provides a baseline for other examples of that wetland type. The monitoring must be conducted over an entire Great Lakes water level cycle to obtain meaningful baseline data.

Illustration
For each wetland type, graphs could show the areal extent of specific wetland types as they change relative to water level and over time.

Limitations
Although not inexpensive, remote sensing, with limited ground checking of zone width, would be the most cost-effective method of monitoring this indicator. The costs might be partially offset if other SOLEC indicators are also monitored using remote sensing.

The extent of each coastal wetland type varies with Great Lakes water level fluctuations. Monitoring must be repeated throughout the Great Lakes water level fluctuation cycle. No one is currently doing this on a regular basis. Conducting the monitoring and detecting human-induced change in an area may not be feasible in the two-year time frame of SOLEC.

Wetland area change caused by human actions may be difficult to measure because (a) natural water level fluctuation can have a dramatic effect on area by type and (b) a historic 'original size' by type for each water level regime is difficult to establish.

Interpretation
This indicator needs to be evaluated in terms of both wetland quality and extent. While some wetlands may decrease in both area and quality due to the lack of water level fluctuation, as on Lake Ontario, the area of other wetlands could remain within the range determined by natural water level fluctuations, but be degraded by other factors, such as sedimentation, excessive nutrients, or invasive species. When interpreting the data, the other coastal wetland indicators that evaluate wetland quality need to be considered. For measuring the variable in a most superficial way, the extent of the wetland remaining could be estimated to the nearest 10% and then divided by 10, providing a score of 1-10. For example, a wetland type that remains at roughly 80% of its original size within a particular water level regime would have a score of 80/10=8.

Comments
The wetland area measured would include the data from indicator #4511, Gain in Restored Wetland Area by Type.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): water, land
Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Gain in Restored Coastal Wetland Area by Type(Indicator ID: 4511)

Measure
Gain in restored wetland area by type.

Purpose
To assess the amount of restored wetland area, and to infer the success of conservation and rehabilitation efforts.

Ecosystem Objective
Sufficient gain in restored wetland area to ensure adequate representation of coastal wetlands by type across their historical range. (GLWQA Annexes 2 and 13)

Endpoint
The endpoint for this indicator needs to be defined and could be as simple as defining a certain amount of Great Lakes areas that should be classified as wetland. There should be enough gain in wetland area to offset any losses to ensure no net loss; however, opportunities for wetland gain may be limited by lack of available sites. Also, the endpoint should consider wetland quality including zones of vegetation and desired species.

Features
This indicator measures additional restored wetland area, not enhancement of existing wetland area. When evaluating this indicator, wetland quality, not just total restored area needs to be considered. High quality examples of each wetland type, based on geomorphology and climatic setting, should be used to define the expected zones of vegetation, sediment characteristics, and plant species in restored wetland. Also, wildlife use, based on baseline high quality wetlands, could be used to evaluate the success of the wetland restoration. Other coastal wetland indicators should be used to help interpret wetland quality.

Illustration
A graph displaying the amount of gained/restored wetland area by type over time.

Limitations
The gain in restored wetland area does not necessarily reflect the quality of the wetland. Also, lack of available sites for restoration would be a limitation.

Data quality may vary because data will be submitted from a number of agencies. Also, because of multi-agency partnerships in most restoration projects, it is crucial to ensure that restored areas are counted only once when agencies submit data from the same project.

Wetland area change caused by human actions may be difficult to measure because (a) natural water level fluctuation can have a dramatic effect on area by type and (b) a historic 'original size' by type for each water level regime is difficult to establish.

Interpretation
By looking at both indicator #4510, Wetland Area by Type, and the gain in restored area within a particular water level regime, it will be possible to determine whether the no net loss goal is being met, or being surpassed with additional gains. Further investigation or incorporation of historical data could be important for Lakes Erie and Ontario and the St. Lawrence River. For many of the wetland types characterizing the Great Lakes shoreline, baseline data for high quality examples exist for both the typical zonation, relation to water depth, and typical plant species of each zone. Baseline data for Lakes Erie and Ontario and the St. Lawrence River are less reliable because of the high level of wetland degradation. In Lake Ontario and the St. Lawrence River, water level control/manipulation has altered the species composition in even the least disturbed wetlands.

Comments
Gain in wetland area will be determined using data reported by agencies that track wetlands restoration, and confirmed by remote sensing. This will allow gain, not just enhancement of existing wetland, to be tracked. Agencies will need to provide documentation about the location of restoration projects and track restoration (i.e. true gain in area) versus enhancement (i.e. modifications to existing area).

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): water, land
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Presence, Abundance & Expansion of Invasive Plants

(Indicator ID: 4513)

Measure

Presence, abundance, & expansion of invasive plants (both native and non-native), such as flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pondweed, cattail, Phalaris, and Phragmites.

Purpose

To assess the decline of vegetative diversity associated with an increase in the presence, abundance, and expansion of invasive plants, and to be used as a surrogate measure of quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

Ecosystem Objective

Coastal wetlands throughout the Great Lakes basin should contain low numbers of invasive plant species with low levels of coverage. (GLWQA Annexes 2 and 13)

Endpoint

Species of invasive plants and the degree of aerial coverage associated with each species, vary by wetland type, lake, region, and latitude, due to differences in geomorphic and climatic conditions. Specific coverage values would have to be established for each wetland type and for each invasive plant species.

Features

Two considerations in assessing the condition of coastal wetlands are quantity and quality. The areal extent of a wetland can be large, but the same wetland can be highly degraded or modified by the dominance of invasive plant species. Similarly, wetland restoration may result in extensive wetlands, but dominance by invasive plant species can reduce the value of such wetlands considerably. This indicator will track the quality of coastal wetlands by assessing the biodiversity of wetland vegetation over time.

Illustration

Graphs will display the of number of invasive (native and non-native) plant species and percent coverage over time. To illustrate this indicator, maps will show how the range of invasive plant species has expanded over time.

Limitations

The presence, abundance, and expansion of most invasive plant species cannot be evaluated solely on the basis of aerial photography or satellite imagery, thus requiring some field visits to locate certain species and monitor their expansion. Once documented, aerial photography may be used to monitor the patch size of some invasive plant species. Certain invasive plant species have been adequately studied, and their detrimental effect on the ecosystem and their ability to expand into certain habitats has been documented. Other invasive plant species have not yet been adequately evaluated, therefore, little is known about their effect on the ecosystem or their ability to expand into certain habitats.

Interpretation

A ranking could be developed based on a combined score of 1) the number of invasive plant species, 2) the coverage value of coastal wetlands dominated by invasive plant species and 3) whether the invasive plants are native or non-native.

Comments

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands that adequately characterize each lake basin will be selected.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **coastal wetlands**, nearshore terrestrial
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Sediment Flowing into Coastal Wetlands (Indicator ID: 4516)

Measure

Suspended Sediment Unit Area Yield (tonnes/km^2 of upstream watershed) for a representative set of existing monitoring sites just upstream of coastal wetlands.

Purpose

To assess the severity of sediment yields flowing into coastal wetlands and potential impact on wetland health.

Ecosystem Objective

To maintain and restore healthy coastal wetlands which are highly dependent on appropriate sediment loads. (GLWQA Annexes 1, 2 and 13)

Endpoint

Wetlands require some sediment to maintain barriers and elevation against scour etc., so the reference value is not zero. A desired endpoint can be set from unit area yields to representative wetlands without sedimentation problems.

Features

Sediment yield is critical to habitat health and is one of the major wetland stressors. Sites throughout the basin can be chosen to represent stream inflow to individual wetlands and it is possible that there is enough existing monitoring to represent the basin-wide situation. The data are already collected, analyzed, and maintained comparably in both countries. There is fairly high variability among the data because stream sediment yields are directly related to flow, which varies depending on precipitation events. Sediment yields are also dependent upon agricultural land management practices and land use. This indicator links to other wetland stressor indicators that have similar causes, including 4560, Nitrate and Total Phosphorus into Coastal Wetlands, and indicator 4519, Number of Extreme Storms. Sediment affects the wetland State/Response indicators including those associated with area by type, invasive plants and wildlife.

Illustration

This indicator could be displayed graphically as tonnes of sediment per km^2 of coastal wetland watersheds (y axis) versus time (x axis). The desired reference point or endpoint could be indicated on the y axis and across the graph.

Limitations

The indicator is developed from flow measurements using stream-specific and regularly updated relationships of flow and sediments.

Interpretation

Interpretation will be based on the magnitude of the difference of the monitoring stream sediment yields from the reference yield. The reference yield will be scored as 10. The greater the difference in the monitored yield, the lower the score. Additional information that could help interpret reasons for stream sediment yield include: weather, conservation practices data, and upstream reservoirs. Data for percentage of silt and clay are also available and can help interpret associated contaminants and whether material is likely to settle out or not.

Comments

This is a clearly understood indicator to which both development and agriculture industries can relate. Excess sediment is of concern not only for its physical smothering, in-filling and light obstruction properties but also for other harmful contaminants it can carry.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water, sediments
Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**, nearshore terrestrial
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Nitrate and Total Phosphorus Into Coastal Wetlands

(Indicator ID: 4860)

Measure

Concentration of nitrate and of total phosphorus just upstream from, or in, a set of Great Lakes coastal wetlands.

Purpose

To assess the amount of nitrate and total phosphorus flowing into Great Lakes coastal wetlands, and to infer the human influence on nutrient levels in the wetlands.

Ecosystem Objective

Maintenance and restoration of more natural levels of nutrients to maximize: species and community diversity, wetland integrity and wetland values. (GLWQA Annexes 3 and 13)

Endpoint

In the growing season, at least one instance of < 0.5 mg/l nitrate and < 0.03 mg/l total phosphorus.

Features

This indicator will assess the concentrations of nitrate and total phosphorus found in and entering Great Lakes coastal wetlands. These are the major nutrients affecting coastal wetlands. Data for this indicator will be collected from the following locations: 1) existing closest stream monitoring sites within 5 km upstream of a coastal wetland (within 10 km upstream if on the Canadian Shield); 2) existing monitoring for Long Range Transport of Air Pollutants (LRTAP) at stations nearest the coastal wetland sites with stream monitoring stations; and 3) proposed in situ monitoring of a representative set of coastal wetlands. Past trends can be constructed using historical stream data, which exists for many years.

The indicator will be updated on an annual basis, as new data are available. Stream sampling data are often collected on the order of 1 sample per month. Concentrations may vary with seasons and events but choice of presence/absence type indicator during the growing season greatly reduces variability. This indicator links to other coastal wetland indicators that assess wildlife affected by eutrophication or reduced habitat diversity (e.g., 4501, Coastal Wetland Invertebrate Community Health; 4502, Coastal Wetland Fish Community Health; 4504, Amphibian Diversity and Abundance in Coastal Wetlands), as well as indicator 4510, Coastal Wetland Area by Type, and indicator 4513, Presence, Abundance and Expansion of Invasive Plants. The in situ sampling piggy-backed on wetland visits proposed for other indicators and will have relatively low associated lab costs.

Illustration

This indicator will be presented using a graph with y axis as % of sites with at least one instance of both <0.5 mg/l nitrate and <0.03 mg/l total phosphorus from May to July, and x axis as time in years. Percentage reaching the endpoint can also be recorded for each of the set of upstream samples (with airborne contribution (LRTAP) concentrations added) and the set of in situ samples in case their trends differ.

Limitations

Low incremental cost assumes (1) no major downsizing of the stream water quality monitoring network, and (2) on-site wetland visits by biologists monitoring other indicators. Total phosphorus has an official standard; nitrate does not. Variation within each wetland will require a general protocol for such factors as storm event avoidance and grab sample location.

Interpretation

The higher percentage of sampled wetlands and streams reaching the endpoint (at least one instance of both < 0.5 mg/l nitrate and <0.03 mg/l total phosphorus from May through to July), the better. A ranking system of 0 to 10 can be used to interpret this indicator, with 0 for no stations reaching the endpoint and 10 for all (100%) stations reaching the endpoint.

Analysis of this indicator must consider recent data from monitoring stations dropped since the previous year's monitoring. For example, if dropped stations were all high water quality, then their omission, rather than just pollution levels, affects the trend in percentage reaching the endpoint.

Comments

In nutrient over-enriched wetlands, a few species out-compete many others reducing biological and social values. One instance of low concentration indicates the site is capable of non-excessive nutrient levels and allows the indicator to avoid (1) the confusion imposed by the high variability in concentration which often occurs among monthly samples, and (2) the need for many more samples to fully assess nutrient level regimes.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): nutrients
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae

Last Revised
Feb. 23, 2000

Water Level Fluctuations (Indicator ID: 4861)

Note: This indicator is listed as both a Coastal Wetland and Nearshore Terrestrial indicator

Measure

For each lake: 1) Mean lake level; 2) Lake-wide annual range in monthly averages; 3) Lake-wide seasonal peak (days after January 1); 4) Lake-wide seasonal minimum (days after September 1); and 5) Elevation Difference between Upper and Lower Emergent Vegetation Extent based on Water Level model (Painter and Keddy, 1992).

Purpose

To assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and to infer the effect of water level regulation on emergent wetland extent.

Ecosystem Objective

To maintain and restore healthy coastal wetlands whose existence and integrity depend on naturally fluctuating water levels (GLWQA Annexes 2 and 17).

Endpoint

The endpoint for this indicator is based on four historic ranges (i.e., data exceeded 0-25%, 25-50%, 50-75%, and 75-100% of the years examined) for each measure per lake. All years of historical data from 1918 to 1959 for Lake Ontario, and from 1918 to 1980 for all other lakes, will be used to set the historic ranges. The endpoint is reached if in the previous 20 years, distribution of data is fairly evenly distributed among the four historic ranges. The endpoint for water level regulation effects is the elevation difference between upper and lower emergent vegetation extent, calculated by application of the Painter and Keddy model to water levels in Lakes Ontario and Superior under a "no regulation" scenario.

Features

Lake levels have a major influence on undiked coastal wetlands and are basic to any analysis of wetland change trends. This indicator uses existing annual summaries of lake and basin-wide water level fluctuations based on daily data. Natural variability will occur in each measure, but will be accounted for in the interpretation method. Yearly data can vary and should be reviewed whenever data for other wetland indicators are collected. Interpretation into the score of 10 (see Interpretation), however, will show far less variability and may be required only every second or third SOLEC cycle. This indicator links to indicator #4510 Coastal Wetland Area by Type, and all wildlife indicators. The data for this indicator are already collected, standardized, easily available and analyzed.

Illustration

One graph per lake of "Correspondence of Previous 20 Years of Water Levels With Historical Distribution" on the y-axis with the x-axis as time in years. Lakes Ontario and Superior will also have a graph of "Effect of Regulation on Extent of Emergent Vegetation Elevation", which will be the difference between pre- and post-regulation modeled values each year. Lakes Michigan and Huron will be illustrated on one graph.

Limitations

Some analysis is required to set historical reference ranges and to calculate emergent vegetation elevation difference. The indicator shows changes from historic distribution of levels but cannot distinguish if changes are due to natural climatic variability or human-induced climate change. The emergent elevations are based on a model using lake level data but not direct field measurements of vegetation extent.

Interpretation

If previous 20 years of data are distributed evenly across the historical range for a measure (i.e., within historical high and low values AND distributed reasonably evenly among the 4 historical ranges), the trend can be interpreted as "good." If a year is beyond high or low historical value OR distribution is becoming highly skewed from a fairly even distribution among the 4 historical ranges, the trend can be interpreted as "bad."

A ranking system of 0 to 10 can be used to determine the trend of the overall indicator (i.e., an aggregate of all five measures). Each of 5 parameters for each lake will receive a score of 0, 1, or 2, depending on how well the previous 20 years of data fit the historical ranges. The total of the scores for the 5 parameters identified under Measure above provides a lake score (maximum of 10). An average of the 4 lakes scores could provide a basin-wide score. The four lakes are Superior, Michigan/Huron, Erie and Ontario. The y axis of the "Effect of Regulation" graphs will be scaled so larger effects score lower; no effect scores 10.

Lake St. Clair is omitted from the basin-wide score since ice jams in the Detroit and St. Clair Rivers can greatly affect ranges and extreme levels. For the same reason St. Clair indicators are restricted to the average level and elevation differences.

Comments

Water levels are important to the public. The importance to wetland integrity, however, of natural level fluctuations is less widely appreciated and use of modelled elevations of emergents, historical ranges and one index for all parameters and lakes may be difficult for public understanding.

Painter, S. and P. Keddy. 1992. Conceptual Emergent Marsh Response to Water Level Regulation. National Water Research Institute, Environment Canada, Burlington Ontario.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): habitat, climate change
SOLEC Grouping(s): **coastal wetlands, nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Area, Quality, and Protection of Lakeshore Communities

(Indicator ID: 8129)

Measure

Area, quality, and protected status of twelve special lakeshore communities occurring within 1 kilometre (km) of shoreline. The twelve special lakeshore communities are sand beaches, sand dunes, bedrock and cobble beaches, unconsolidated shore bluffs, coastal gneissic rocklands, limestone cliffs and talus slopes, lakeplain prairies, sand barrens, arctic-alpine disjunct communities, Atlantic coastal plain disjunct communities, shoreline alvars, and islands.

Purpose

To assess the changes in area and quality of the twelve lakeshore communities, and to infer the success of management activities associated with the protection of some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore.

Ecosystem Objective

This indicator supports Annex 2 of the GLWQA.

Endpoint

No net loss in area or quality of the twelve lakeshore communities.

Features

The twelve lakeshore communities presented in this indicator are identified in "Land by the Lakes," a paper from SOLEC '96, as some of the most ecologically significant habitats in the terrestrial nearshore. This indicator will map the location and extent of these lakeshore communities from existing studies (where available), Biological Conservation Databases, remote sensing and aerial photos, and land use planning data. The quality of the lakeshore communities will be ranked using criteria such as size, condition, and landscape context. In addition to location and quality, this indicator will identify the protection status related to each identified lakeshore community (e.g., public conservation ownership, private conservation ownership, protective land use policies), as well as the severity of threats to the quality of each community, such as the presence of invasive exotic species.

Illustration

Colour mapping could show the distribution of each lakeshore community, ranked by quality or degree of protection for each lake, ecoregion, or the basin. Bar charts could highlight changes over time for each community, or compare the current area to estimates of the original area. A preliminary analysis of sand dune complexes across the Great Lakes basin by The Nature Conservancy's Great Lakes Program provides an example of how the results could be portrayed. In addition to charts showing the percentage of protective ownership, this model illustrates the severity of different types of stresses affecting this community.

Limitations

Data collection may be difficult for many reasons. Collection of detailed data on a regular basis may be difficult due to the large area and the number of different jurisdictions to be examined. Identification of lakeshore communities using aerial photography may prove easy for some communities and more difficult for others. Lastly, information on location and quality for some lakeshore communities is incomplete, therefore, this indicator will require some expense to establish a reliable baseline.

Interpretation

A baseline of the area of each of the twelve lakeshore communities will be established for comparison with periodic monitoring every 3-5 years to identify changes. As more information becomes available, this indicator could provide a more detailed analysis of changes in area and habitat quality within each of the communities, as well as a better understanding of the threats to these communities. Quality rankings for each occurrence of a lakeshore community can be based on techniques developed by state/provincial Heritage Programs, which establishes classes for size, assesses condition based on disturbance and the presence/absence of sensitive species, and rates the degree of connection and buffering provided by the surrounding landscape context.

Comments

This indicator provides easily understood information on the ongoing loss of the best of Great Lakes shoreline communities. The information conveyed by this indicator will help to focus attention and management efforts on the communities undergoing the greatest rate of change.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): land, biota
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Extent of Hardened Shoreline (Indicator ID: 8131)

Measure
Kilometres of shoreline that have been hardened through construction of sheet piling, rip rap and other erosion control shore protection structures. (Does not include artificial coastal structures such as jetties, groynes, breakwalls, piers, etc.)

Purpose
To assess the amount of shoreline habitat altered by the construction of shore protection, and to infer the potential harm to aquatic life in the nearshore as a result of conditions (i.e., shoreline erosion) created by habitat alteration.

Ecosystem Objective
Shoreline conditions should be healthy to support aquatic and terrestrial plant and animal life, including the rarest species. This indicator supports Annex 2 of the GLWQA.

Endpoint
No net increase in the amount of hardened shoreline along any of the Great Lakes or connecting channels.

Features
There is limited historical data available on this indicator, but estimates of the extent of shore protection were made as part of an IJC reference in 1992. Data collection for this indicator could include estimates based on aerial photography and limited field studies, with a focus on Areas of Concern and sites identified from the 1992 IJC data where shoreline hardening appears to be increasing.

Illustration
A bar chart for each lake, or reaches within lakes, could document the annual change in the amount of hardened shoreline.

Limitations
The field data needed to assess the actual length of new hardened shoreline each year would be costly. A commitment to collect data within selected areas every 5 years might be more achievable.

Interpretation
The degree of negative impact to aquatic life in the nearshore will vary depending on the design of the protection and on the antecedent conditions. Some types of hardened shoreline induce more severe impacts than do others. A classification scheme that reflects the degree of impacts from different types of shore protection should be developed, based on a literature review.

Comments
Some types of shore protection create conditions that are not hospitable to aquatic life in the nearshore. This indicator will measure the extent to which this is occurring.

Unfinished Business
- Need to provide a baseline year and a baseline amount of hardened shoreline for the endpoint.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): nearshore terrestrial, land use
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Nearshore Land Use (Indicator ID: 8132)

Measure

Land use types, and associated area, within 1 kilometre (km) of shore. Land use types could include urban residential, commercial, and industrial, non-urban residential, intensive agriculture, extensive agricultural, abandoned agricultural, closed-canopy forest, harvested forest, wetland and other natural area.

Purpose

To assess the types and extent of major land uses within 1 km from shore, and to identify real or potential impacts of land use on significant natural features or processes, particularly on the twelve special lakeshore communities.

Ecosystem Objective

Healthy nearshore terrestrial ecological communities will be maintained. This indicator supports Annex 2 of the GLWQA.

Endpoint

No net loss or alteration of significant natural features or processes from current conditions.

Features

This indicator will track trends in terrestrial nearshore land uses over time (ideally 5 to 10 year periods) and focus on identifying areas experiencing the greatest changes in land use intensity over time. To identify and map terrestrial nearshore land uses, this indicator will rely on a variety of methods, including remote sensing; aerial photography; available land use planning data for areas identified as already experiencing rapid land use changes (e.g., urban areas and cottage development); municipal data on building permits; and official plan/zoning bylaw amendments. Subsequent yearly monitoring will establish an increase or decrease in the extent of major land use types. This indicator is related to indicator #8136, Nearshore Natural Land Cover.

Illustration

For each lake basin, lake, jurisdiction, and ecoregion, a table or graph will display annual changes in the area and degree of interspersion of each land use.

Limitations

Data collection may be difficult for many reasons. Collection of detailed data on a regular basis may be difficult due to the large area and the number of different jurisdictions to be examined. Differences in types of land use planning data collected by jurisdictions may also hamper the collection of consistent data to support this indicator. Some limited historical data are available on land use types, but these data are focused on specific areas. A few basin-wide studies have been conducted that would provide a basic description of land use trends (e.g., U.S. National Shoreline Inventory from the early 1970s and a recent IJC water levels reference study) but it may be difficult to compare these data due to differences in methodology and generalizations that may have been used.

Interpretation

Developing a baseline for this indicator will require both a review of existing data sources to determine their usability, and a discussion among agencies to establish a common list of land use types and parameters. Computerized analysis of satellite imagery may provide a cost-effective means of data collection for the overall nearshore area. A more detailed study and ground-truthing of selected areas, however, will be needed to assess the relationship of land use changes to the loss or alteration of significant natural features and processes. In particular, results from this indicator should be compared to results from indicator 8129, Area, Quality, and Protection of Special Lakeshore Communities, to assist in identifying land use change patterns that threaten natural habitats.

Comments

The twelve special lakeshore communities are sand beaches, sand dunes, bedrock and cobble beaches, unconsolidated shore bluffs, coastal gneissic rocklands, limestone cliffs and talus slopes, lakeplain prairies, sand barrens, arctic-alpine disjunct communities, Atlantic coastal plain disjunct communities, shoreline alvars, and islands.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore terrestrial**, land use
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Nearshore Plant and Animal Problem Species (Indicator ID: 8134)

Measure
Type and abundance of plant and animal problem species, including white sweet clover, leafy spurge, spotted knapweed, garlic mustard, white-tailed deer, and Brown-headed Cowbird, within 1 kilometre (km) from shore.

Purpose
To assess the type and abundance of plant and animal problem species in landscapes bordering the Great Lakes, and to identify the potential for disruption of nearshore ecological processes and communities.

Ecosystem Objective
Healthy nearshore ecological processes and communities in the Great Lakes should be free of disruptive problem species. Healthy populations of grassland/forest interior bird species should be undisturbed by parasitic species. Preserve/restore larger intact ecosystems to support healthy nearshore ecological processes and communities in the Great Lakes. This indicator supports Annexes 2 and 17 of the GLWQA.

Endpoint
1) For problem plant species, the desired outcomes are: a) eradication at key sites, defined as excellent examples of representative communities or globally rare communities, and b) a downward trend from current levels in the abundance of these species in other nearshore areas.

2) For deer, the desired outcomes are: a) the successful regeneration of all native plant species that are browsed by deer, including white cedar, Canada yew, northern red oak, Trillium grandiflorum; b) intact vegetation structures (e.g.,canopy, sub-canopy, shrub and forest floor layers) within areas browsed by deer; and c) the deer density is below a level defined regionally as a sustainable population.

3) For cowbirds, the desired outcome is a decrease in parasitism to levels that allow recruitment by host bird species (e.g., Wood or Swainson's Thrush, Veery, Red-eyed Vireo, Black-and-white Warbler, Ovenbird, Savannah Sparrow, Bobolink) to meet or exceed the replacement rate of at least 2.0 young fledged/nest/year.

Features
This indicator will track changes in presence and abundance of plant and animal problem species over time. Exotic plant species are indicative of disrupted ecological processes in ecological communities. They tend to displace native species and further disrupt the dynamics of plant communities. White sweet clover, leafy spurge and spotted knapweed are found in open habitats while garlic mustard occurs in forests. White-tailed deer and Brown-headed Cowbirds are indicative of landscape changes where there is much habitat fragmentation and a high proportion of early successional habitats. Population levels of problem species and forest or grassland interior bird species that serve as host to cowbirds should be monitored at selected sites along each of the Great Lakes in landscapes ranging from highly fragmented to unfragmented. Vegetation monitoring within wintering areas for deer should also be carried out. Special attention should be paid to those areas experiencing considerable change. For example, the indicator should communicate if the problem species are expanding or reducing their influence in areas at the edge of their range and/or in areas undergoing restoration. Monitoring at reference sites scattered along the shoreline will be critical.

Illustration
For each lake, this indicator will present changes in mean number/productivity per unit area per site for problem species or for forest and grassland interior bird species that serve as host to cowbirds. This indicator will divide sites into fragmented and unfragmented landscapes bordering each side of each Great Lake. The illustration for this indicator will display on a bar chart trends by year for each site representing a fragmented and unfragmented landscape. This indicator will also display the occurrence and recruitment for white cedar, northern red oak, Canada yew, Trillium grandiflorum, as well as the vegetation structure at these same sites to show the effects of problem species on natural communities.

Limitations
Distributions of native and alien species within 1 km of Great Lakes shorelines are generally known, although densities are poorly described. Densities of some species (deer, Swainson's Thrush, Red-eyed Vireo, Black-and-white Warbler) are known at only a few locales, or not at all. Data on presence/absence of problem species are relatively easy to collect but would require basin-wide coordination of botanists, deer biologists, and ornithologists to accomplish. Collection of data on the densities of problem species requires training, standardized data collection techniques, and accounting for observer bias. Data on the productivity of problem species are very costly to obtain, especially on a sustained basis. It would be best to collect these data at longer intervals.

Interpretation
A number of other factors will need to be considered in interpreting this indicator. Changes in abundance, density, and productivity of native nearshore ecological communities are caused by factors other than the degree of habitat fragmentation, the amount of available habitat, and interactions with invasive exotic species. Factors such as connectivity and the survivorship of birds on migration routes and wintering areas will influence abundance density and productivity, and therefore, will affect the interpretation

of this indicator. In general, increases in interior species and decreases in problem species, compared to a baseline of current populations, should be interpreted as good.

Comments

The list of problem species to be monitored for this indicator needs to be narrowed down. The number and location of monitoring sites for this indicator, as well as a definition of fragmented and unfragmented, need to be determined for this indicator. If the interface between aquatic and terrestrial ecosystems is addressed, purple loosestrife and Phragmites australis should be added to the list. Changes in responses (e.g., management efforts) to problem species should also be documented.

Unfinished Business

- Need to determine the level of parasitism by the cowbird that will allow recruitment of host bird species to meet or exceed the replacement rate of at least 2.0 young fledged/nest/year.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Contaminants Affecting Productivity of Bald Eagles (Indicator ID: 8135)

Measure
1) Concentrations of DDT Complex, PCB, PCDD, PCDF and other organic contaminants and mercury and other heavy metals in Bald Eagle eggs, blood, and feathers; 2) number of fledged young produced; and 3) number of developmental deformities.

Purpose
To assess the number of fledged young, number of developmental deformities, and the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers. The data will be used to infer the potential for harm to other wildlife and human health through the consumption of contaminated fish.

Ecosystem Objective
This indicator supports Annexes 2, 12 and 17 of the GLWQA.

Endpoint
1) Concentrations of organic and heavy metal contaminants less than the NOAEL in eggs, blood, and feathers; 2) productivity rate of 1.0 young per occupied breeding area annually; and 3) no observed developmental deformities in nestlings.

Features
Annual productivity data exists for Bald Eagle breeding areas in the Great Lakes since early 1960s. Data exists on the concentrations of contaminants in eggs and feathers since late 1960s. Annual inspection of nestlings during banding provides rates of expressed deformities.

Illustration
For each lake, and subunits within each lake, the following trends will be shown graphically: concentrations of organic and heavy metal contaminants; yearly productivity; and, areas where deformities have been documented. Illustrations for this indicator will also present territories and habitat suitability indices. The data from 1970-1998 will be displayed; data prior to 1970 may have inconsistencies.

Limitations
Eagles do not nest on every shoreline of every Great Lake. They are highly viewed by the public and not a good laboratory animal. They can be linked with the presence of colonial waterbirds and osprey using conversion factors to generate a better geographic representation.

Interpretation
Biological endpoints specifically related to PTS addressed by the GLWQA are well known and are published in the peer-reviewed literature on cause-effect linkages.

Comments
This indicator is one of few that has been tested in the field. It is one of the best indicators identified by the IJC in relation to the GLWQA because long-term data are available and there are known reproductive effects.

Reproductive failure, depressed reproduction, increased incidence of teratogenic effects, and behavioral effects (related to food gathering or parenting skills) are used as endpoints and related various PTS concentrations. Since different PTS have different effects, multiple endpoints are necessary. Also, since the effects change based on concentrations in the biological matrix measured (blood, egg, feather), multiple endpoints are necessary so that progress toward recovery from PTS can be measured.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised
Feb. 23, 2000

Extent and Quality of Nearshore Natural Land Cover

(Indicator ID: 8136)

Measure

Percent of natural land cover types within 1 km of the shoreline that meet minimum standards of habitat quality.

Purpose

To assess the amount of natural land cover that falls within 1 km of the shoreline, and to infer the potential impact of artificial coastal structures, including primary and secondary home development, on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

Ecosystem Objective

Maintain the health and function of a representative number of shoreline natural land cover types. This indicator supports Annex 2 of the GLWQA.

Endpoint

Shoreline natural land cover types will be 1) well represented, and 2) healthy. To determine if natural land cover within 1 km of the shoreline is well-represented and healthy, additional work is required to develop quantitative endpoints.

Features

This indicator will track changes in the number of hectares of coastal communities on the Great Lakes over time. Natural land cover within 1 km of the shoreline generally includes areas that: provide important habitat to migrating birds; contribute sediment and chemical loadings to streams and the lake; preserve the integrity of river-mouth wetlands; and sustain other nearshore natural processes. Only cover type occurrences that meet minimum quality standards would be included. These standards could be based on occurrence size (e.g., over 2 acres), condition, and landscape context, using similar criteria to those in indicator 8129, Special Lakeshore Communities. It is not likely that the natural land cover within 1 km of the shoreline has been assessed in many areas around the Great Lakes. A baseline should be established (i.e. 2000) with re-mapping occurring every ten years (i.e., 2010, 2020) to track trends in land cover change. Data from this 1 km zone can be linked with land cover analysis occurring further inland to report on the health of entire watersheds. Data collection for this indicator should be done in conjunction with indicator 8132, Nearshore Land Use.

Illustration

The percentage of land cover within 1 km of the shoreline can be mapped using remote sensing products, such as satellite imagery, and then displayed on geographic information systems (GIS). Different types of vegetation communities can be analyzed and displayed for a particular area of shoreline, or for the entire shoreline of a Great Lake using the GIS. The resulting information could be portrayed as bar charts for each area, showing both comparisons between cover types and changes over time.

Limitations

Information on historical vegetation communities is likely available in surveyors records, early journals, and old air photos and will need to be assembled. Although this is a relatively inexpensive indicator, because much of the remote sensing mapping and GIS software is likely already available, there will be costs involved in adapting existing data to report on the 1 km shoreline zone (i.e., joining maps, integrating data at different scales). Establishing a baseline should not be very costly. Costs will rise as this indicator is related to other information (see Interpretation field).

Interpretation

This indicator will show whether the nearshore natural land cover is increasing or decreasing in comparison to the baseline, and what kinds of changes are taking place. The information contained in this indicator will be more useful if coupled with other indicators that measure changes in other components of the Great Lakes nearshore terrestrial ecosystems. For example, information on changes in the presence and abundance of birds, reptiles, amphibians, plants and other nearshore terrestrial species dependent on land cover within 1 km of the shoreline will provide a better understanding of how changes in the percentage of natural land cover affects the ecosystem.

Comments

The information needed to develop endpoints for this indicator is likely available, but will require a literature search and discussions with additional experts. Representatives from the Long Point and Whitefish Point Bird Observatories should be consulted on the requirements of migratory birds in the shoreline zone. Assembling the historical and current vegetation community information for the 1 km shoreline zone should be undertaken in partnership with other SOLEC groups who are interested in adjacent watersheds because much of the baseline information will be common to both interests.

A more detailed definition of the types of natural land cover to be included in this indicator needs to be developed. Data collection efforts should use satellite imagery at the best resolution available (i.e., 5 or 20 metres) and refine information for specific areas of interest along the lakes using aerial photography.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environment integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Nearshore Species Diversity and Stability (Indicator ID: 8137)

Measure
The type and number of plant and wildlife species, and vegetation regeneration rates within the nearshore area, defined as the area within 1 kilometre (km) of the shoreline.

Purpose
To assess the composition and abundance of plant and wildlife species over time within the nearshore area, and to infer adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

Endpoint
Naturally-regenerating nearshore plant and wildlife communities with a diversity of native species equivalent to historical populations.

Features
This indicator will track changes in nearshore plant and wildlife species composition and abundance over time. Plant and wildlife species in the nearshore area are sensitive to changes in environmental and habitat conditions. This indicator could draw on several existing sources of information, as well as encourage new data collection. Ontario, Canada, and most States have comprehensive data sets for breeding birds on a geo-referenced 10 km x 10 km grid that is periodically updated. Similar data are available for herptiles, mammals, and trees, although they are less likely to be comprehensive. For some sites along the shoreline, historical data are available on the regeneration of species such as White Cedar, White Pine, and Canada Yew. Changes in regeneration rates of these species, or of other communities such as lichens, are indicative of either local pressures such as deer browsing, or broader-scale environmental changes, such as air pollution. As new data becomes available (on a 10-15 year cycle for comprehensive coverage), changes over time can be observed.

Illustration
Using existing breeding bird data, a map could be readily generated showing shoreline cells (i.e. the number of species within their normal breeding range) with the number of breeding species within each as a percentage of the total number of species within their breeding range.

Limitations
Comprehensive data is not available for all species groups, and data collection is laborious and largely volunteer-based. Even for the best data sets, such as the data set on breeding birds, coverage is incomplete in more remote areas. Historical data on regeneration rates is highly site-specific, and available for relatively few sites.

Interpretation
These data can be compared to the total number of species that could be expected within each shoreline cell. For some species, population ratios could also be derived as well, as a comparative measure of stress - for example, classing the population of a species within each cell as abundant, common, scarce, or rare. The nature of observed changes over time can indicate different kinds of stresses. For example, a uniform decrease in the diversity of breeding species could indicate a broad-scale stress such as climate change; decreases only on urban fringes while more remote areas stay the same would more likely point to local habitat changes. It would be useful to divide the data between resident and long distance migrant birds in order to separate local from broad impacts.

Comments
As part of the indicator development, priority species, which could be groups of birds, woodland frogs, etc., should be selected.

In regional studies carried out in southern Ontario by the Federation of Ontario Naturalists, this method showed a range in values from 100% of expected species in good habitats to less than 70% in areas with degraded conditions.

Unfinished Business
- Need to develop a more quantitative endpoint.

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised
Feb. 24, 2000

Community/Species Plans (Indicator ID: 8139)

Measure
Number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities — those within 1 kilometre (km) of the shoreline — and federally/nationally listed endangered, threatened, and vulnerable species.

Purpose
To assess the number of plans that are needed, developed, and implemented to protect, maintain or restore high quality, natural nearshore communities and federally listed endangered, threatened, and vulnerable species, and to infer the degree of human stewardship toward those communities and species.

Ecosystem Objective
Programs should be responsive to the degradation of shoreline communities and species.

Endpoint
Implementation of plans that contained recommended action steps and associated timetables to maintain/recover all significant nearshore natural communities and endangered/threatened/vulnerable species populations identified to date within the nearshore area.

Features
This indicator will compare the number of plans that are needed, developed, and implemented over time. Plans are needed for any species or community that is officially designated as endangered, threatened, or vulnerable (rare) at the federal/national level. The plans will describe the existing community/species status by addressing natural quality, threats, signs of disturbance; natural diversity; rare species (communities) and population size; reproductive success, threats, and recovery needs (species); and recommended action steps. Well-crafted plans will enable monitoring and appropriate conservation measures over time. Implementation of these plans is defined as tangible, on-the-ground management activities that can be shown to be making a measurable difference in the community/species status.

Illustration
To illustrate this indicator, a bar chart will be presented that summarizes the number of plans needed, developed, and implemented for each lake, and tracks progress over time.

Limitations
Tracking the communities/species needing plans and with plans developed should be relatively easy, in conjunction with the federal/national agencies with responsibilities for endangered species. Collecting and analyzing data on implementation in a consistent way may be more difficult.

Interpretation
This indicator should provide a relatively straightforward measure of the attention devoted to communities/species at risk. However, the actual success of these measures will depend largely on the adequacy of the plans and their implementation. Research should be encouraged to address the relationship between the number of plans implemented and the actual maintenance/recovery of natural communities and endangered/threatened/vulnerable species populations.

Comments

Unfinished Business
- Need to determine a reference value that will be used to quantify this endpoint. For example, the endpoint for this indicator might be the implementation of a certain percentage of plans from a total number identified as needed during a baseline year. Or the reference value could be implementation of all plans developed during the previous year.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): biota
Related Issue(s): stewardship
SOLEC Grouping(s): **nearshore terrestrial**, societal
GLWQA Annex(es):
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Shoreline Managed Under Integrated Management Plans

(Indicator ID: 8141)

Measure

Percent of shoreline managed under an integrated shoreline management plan. An integrated shoreline management plan is one that includes consideration of coastal processes, aquatic habitat, and designates appropriate setbacks, etc. and is incorporated into local planning documents (e.g. a municipal Official Plan).

Purpose

To assess the amount of Great Lakes shoreline managed under an integrated management plan, and to infer the degree of stewardship of shoreline processes and habitat.

Ecosystem Objective

Programs should be responsive to the degradation of shoreline communities and species.

Endpoint

The target is 100% of shoreline under "good" pro-active management.

Features

This indicator will track trends in integrated shoreline management plans over time. It will point to areas of the Great Lakes shoreline that are subject to poor or no coastal management. These trends can be used to direct future shoreline management activities.

Illustration

For each of the lakes, this indicator will display a map of shorelines and highlight segments under poor, moderate and good management. This indicator could also be displayed using a pie chart that illustrates the percent of shoreline under the three types of management.

Limitations

Information on quality of shoreline management plans has not been measured across the Great Lakes basin. Existence of shoreline management plans indicates an intent to manage the shoreline accordingly, but does not demonstrate actual compliance or implementation. However, an integrative plan, one that is adopted/incorporated into land use planning documents, does demonstrate serious intent. It is difficult to determine compliance with the plan, or calculate how many zoning variances or amendments have been granted, and it would be too much effort to measure. By focusing on integrated plans, this indicator addresses only part of shoreline planning efforts. Other management plans and programs, including efforts of local municipalities, non-government agencies and the private sector could be considered as these are becoming increasingly important and will continue into the future.

Interpretation

To determine the percentage of shoreline under "good" pro-active management, this indicator could use the following 3- tiered ranking: "poor" = no plan at all; "moderate" = an old plan or a new one that has not actually been adopted; and "good" = an integrated plan that has been incorporated into land use documents. This information could be collected through a survey of shoreline management agencies. Results should be easy to present in an understandable format.

Comments

Some initial research on the potential for integrated shoreline management planning by province and states has been done by Patrick Lawrence at University of Waterloo, along with a focus on continued research on the capacity of Ontario municipalities to undertake Great Lakes shoreline management.

Unfinished Business

Relevancies

Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **nearshore terrestrial**, land use, societal
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 24, 2000

Artificial Coastal Structures (Indicator ID: 8146)

Measure
The number and type of artificial coastal structures (including groynes, breakwalls, riprap, piers, etc) on the Great Lakes shoreline. Artificial coastal structures include structures that extend into shallow waters at an angle from the shoreline, or are placed offshore for the purpose of breaking the force of the waves. They are distinct from the hardened shoreline works described in indicator 8131, Hardened Shoreline, which modify the shoreline edge itself.

Purpose
To assess the number of artificial coastal structures on the Great Lakes, and to infer potential harm to coastal habitat by disruption of sand transport.

Ecosystem Objective
Limit impact to natural features and processes in the terrestrial nearshore and nearshore waters environments. This indicator supports Annex 2 of the GLWQA.

Endpoint
Modification or removal of artificial coastal structures which are shown to negatively affect coastal sand transport, and restoration of natural coastal transport and deposition processes.

Features
This indicator will present trends in the number of coastal structures over time. From aerial photos and existing data sets, a baseline of artificial shoreline structures will be established. Yearly monitoring will be performed to determine if there is an increase or decrease in the structures. An increase will signify potential increased coastal sand transport disruption.

Illustration
A graph with the number of artificial structures on the y axis and the year on the x axis.

Limitations
It may be difficult to monitor the number of structures on a yearly basis and correlate with the degree of disruption of sand transport in specific sites. Monitoring could be done every 3-5 years, or in periods directly following high lake levels, when many of these structures tend to be built.

Interpretation
An increase in the number of artificial shoreline structures in comparison to the baseline will signal a disruption of the coastal process of sand transport.

Comments
Refer to IJC water level reference study for a classification of shore protection types and summaries of the % length by lake and shoreline reach.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): nearshore waters, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Contaminants Affecting the American Otter (Indicator ID: 8147)

Measure

1) Concentrations of heavy metals (e.g., Hg, Pb, Cd) found in hair, blood, liver, and brain of the American otter; and 2) concentrations of DDT and metabolites, PCBs/ PCDFs/PCDDs, Dioxin, and other organic contaminants found in fatty tissues, liver, and blood of the American otter.

Purpose

To assess the contaminant concentrations found in American otter populations within the Great Lakes basin, and to infer the presence and severity of contaminants in the aquatic food web of the Great Lakes.

Ecosystem Objective

This indicator supports Annexes 1, 2, 12 and 17 of the GLWQA.

Endpoint

1) Maintenance of otter populations in the upper lakes, and restoration of sustainable otter populations to lower Lake Michigan, Lake Ontario and Lake Erie watersheds and shorelines; 2) Great Lakes shoreline and watershed populations of American otter should have an annual mean production > 2 young/adult female; and 3) concentrations of heavy metal and organic contaminants should be less than the NOAEL found in tissue samples from mink as compared to otter tissue samples.

Features

American otters are a direct link to organic and heavy metal concentrations in the food chain. The species has primarily a piscivorous diet, but feeds on a wide array of other aquatic organisms. It is also more sedentary than avian species associated with aquatic food chains and subsequently synthesizes contaminants from a smaller area. It has an appropriate application to measure environmental contaminants on a Great Lakes level, but also on a localized scale. Changes in the species population and range are also representative of anthropogenic riverine and lacustrine habitat alterations. Indications of contaminant problems have been noted by decreased population levels, morphological measures (i.e. baculum length) through necropsies and declines in fecundity. Most State resource management agencies perform necropsies to determine an index of fecundity, deformities, growth rates, age and general health of a given population. Fecundity data from necropsies should be expressed by county and provincial management district annually. Limited toxicological studies have been conducted on Great Lakes otter. Trapping data has been intermittently available since 1835 in the Great Lakes region as an index of species abundance. In Ontario and the Great Lake States, except Ohio, trapping success has been used to model populations.

Illustration

Annual trapping success expressed by total killed and number of otter killed/trapper by county and provincial management district adjacent to Great Lake shorelines from 1950 to the present. Contaminant concentrations and trapping success data could be presented as bar charts showing trends over time, or on a map of the Great Lakes basin showing comparative data among management districts.

Limitations

American otters are difficult to maintain for controlled experiments and are highly visible to the public. There is very little toxicological data available on the species for the Great Lakes. Otters have limited populations in the lower Great Lakes. The method of modeling otter populations by harvest success and using indices of fecundity does not accurately measure population levels in the Great Lakes. Little published data exists on the ecology of otters in the Great Lakes region.

Interpretation

Interpretation of this indicator may prove difficult since the ecology of the species and toxicological profiles from the region remain essentially unknown. No data are available on cause and effect linkages for otter in the Great Lakes. Otter are usually compared to contaminant levels in mink because the end points of a toxicological effect are better understood.

Comments

The potential of the American otter as a Great Lakes Indicator makes intuitive sense. However, more information on its ecology and cause and effect linkages to contaminant problems in the Great Lakes region need to be determined to increase the utility of this indicator.

Resource management agencies should be encouraged to search for and monitor otter toilets on or near Great Lake shorelines for activity annually to note changes in distribution and stability in populations in relationship to sub-units of the Great Lakes that are known to be contaminated.

This proposed indicator was the most contentious of the nearshore terrestrial set, with some commenters suggesting that it be dropped, or replaced with monitoring of otter reproduction. In their view, otter reproduction would provide a measure that is more useful in assessing progress toward the GLWQA objectives versus evidence of reductions inferred from chemical analyses and conservative benchmarks. There is also concern that otter contaminant monitoring duplicates the mink indicator.

In response, other reviewers noted that mink are less common than otters in Lake Superior island environments (where they could provide an indicator that would not be influenced by mainland anthropogenic influences), and that mink are extremely problematic to study in the field. Otter differ entirely from mink in their habits and habitats. Otter are far more easy to trap safely and study in the field, and transmitter durations of 3-5 years are possible. They are observable during the day, and their sign is more obvious than that of mink. The territorial behavior of the American otter facilitates the determination of population densities and assists in monitoring efforts. They also live longer than mink, therefore, they synthesize environmental influences for a longer period. Study skins and furs up to 150 years old are available, allowing a historical analysis of metal concentrations in hair. This historical information could not be collected using mink. Literature worldwide documents anthropogenic toxins as one reason for otter populations declining in many parts of the world.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): coastal wetlands, **nearshore terrestrial**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised

Feb. 24, 2000

Protected Nearshore Areas (Indicator ID: 8149)

Measure

The percentage of the Great Lakes shoreline under various levels of protection in six classes as defined by the International Union for the Conservation of Nature (IUCN). The six IUCN classes are 1) strict protection, such as nature reserves and wilderness; 2) ecosystem conservation and recreation, such as national parks; 3) conservation of natural features, such as natural monuments; 4) conservation through active management, such as wildlife management areas; 5) protected landscapes/seascapes; and 6) managed resource protected areas, such as sustainable use areas.

IUCN. 1994. Guidelines for Protected Areas Management Categories. Commission on National Parks and Protected Areas with the assistance of World Conservation Monitoring Centre. Gland, Switzerland, and Cambridge, U.K.

Purpose

To assess the kilometres/miles of shoreline in protective status. This information will be used to infer the preservation and restoration of habitat and biodiversity, the protection of adjacent nearshore waters from physical disturbance and undesirable inputs (nutrients and toxics), and the preservation of essential habitat links in the migration (lifecycle) of birds and butterflies.

Ecosystem Objective

The Great Lakes shall be free of... net loss of fish and wildlife habitat (GLWQA, Annex 2, item xiv). Also relates to several of Lake Superior LaMP's Habitat Objectives including: land and water uses should be designed and located in harmony with the protective and productive ecosystem functions; degraded features should be rehabilitated or restored; and, land use planning and regulation should eliminate or avoid destructive land-water linkages, and foster healthy land-water linkage.

Endpoint

Significant increase in extent of Great Lakes shoreline within formal protected areas.

Features

The reference values are the kilometres/miles of shoreline which are protected as a percent of the total shoreline and the percent of increase or decrease over time as measured every two to four years.

Illustration

For each selected area (e.g., basin-wide, lake, special shoreline community, ecoregion, etc.) graphs will be displayed with the percentage of protected area on the y axis and years on the x axis. Additionally, for each selected area, maps will be displayed that show the protected shoreline and its class of protection.

Limitations

Data on national parks and RAMSAR sites should be relatively easy to obtain. However, data from other locations require the cooperation of state/provincial and local authorities, who may not always have the resources to collect or maintain this information. If baseline data is not readily available, collecting the data will be resource-intensive, and therefore expensive. Subsequent data updates will require only moderate expense. This indicator is useless unless the data inventory is kept up to date and there is consistency in data treatment (database management and GIS) which will require readily available expertise, a continuing, low-level, effort in data management, and a consistent approach.

Interpretation

Once the baseline is established, the percent of the shoreline in protected status can be tracked. "Bad" or "good" trends will be determined by how the percent of the shoreline in protected status is changing over time. An increase in the percent of shoreline in protected status would be considered "good;" a decrease would be considered "bad." The indicator may be complemented by information on the status (ecological integrity, quality) of wetlands, natural land cover along the shoreline, and information on special communities. It may be interesting to show where protected areas and AOC/RAP or Biodiversity Investment Areas coincide, and where the information for this indicator is useful for the evaluation of RAPs or Biodiversity Investment Areas.

Comments

A protected area database has been kept at Environment Canada; whether it is up-to-date or not is unknown. Precise spatial information (precise location and extent, which part of the shoreline, how far inshore) is either not available or poor. In Canada, data for RAMSAR sites, national parks, or MAB sites should be easy to locate. It is not known how often this data is updated, or whether the sites are periodically monitored for their quality (ecological integrity). In the U.S., data on protected areas would have to be compiled from federal and state agency sources. A useful starting point for relevant data can by found in the Environmental Sensitivity Atlases for each of the lakes and connecting channels.

This indicator overlaps with coastal wetland indicators. It would be good to link the information with an indicator on the location, extent and quality of wetlands; also, to what extent these wetlands are protected. The indicator may need some refinement to express "representativeness" (proportion of special lakeshore habitat types included) or better links to "Important Bird Areas", or conservation plans.

MAB	Man and the Biosphere. Initiated by UNESCO to address problems relating to conservation of resources, resources systems, and human settlement development.
RAMSAR	The Convention on Wetlands, signed in Ramsar, Iran in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
UNESCO	United Nations Educational, Scientific and Cultural Organization

Unfinished Business

Relevancies

Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **nearshore terrestrial**, societal
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Urban Density (Indicator ID: 7000)

Measure
Human population per square kilometre of existing and proposed development areas. Total area is adjusted to exclude parks and other designated greenspace.

Purpose
To assess the human population density in the Great Lakes basin, and to infer the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

Ecosystem Objective
Socio-economic viability and sustainable development are generally accepted goals for society.

Endpoint
The most efficient and ecologically sustainable conditions will occur when large urban centres are intensively developed with a high population density. The contrary exists for sparsely populated rural areas — the lower the population density the less stress is imposed on the ecosystem. As a corollary, new growth is best accommodated by adding to the high density area rather than the lower density rural areas.

Features
Urban density is a relative measure of efficiency. In general, and other things being equal, higher density land use is less energy and resource consuming and thus is more efficient from an ecosystem perspective. For example, transportation in higher density areas is less resource demanding since distances are shorter and public transportation is often more available and inexpensive. Consequently, air pollution should be lower in more densely populated areas. In addition, since inefficient land use for urban development implies loss of land use for natural and other purposes there are significant biodiversity dimensions to inefficient land use. In general, the less land used for development, the greater the opportunities that exist for natural biodiversity goals to be met. Urban densities have been declining over time as urban development has become much more sprawling with the vast majority of new development occurring on former agricultural or natural lands. This has resulted in greater reliance for urban residents on the automobile as virtually the only method of public transit for these widespread and low density new communities has become impractical. Information for this indicator needs to be collected perhaps every 5 or 10 years as changes in density take place relatively slowly.

Illustration
This indicator will be displayed by a numerical ratio of population to land area (population per square kilometre).

Limitations
This indicator is useful in comparing municipalities to each other, but would need to be aggregated into an index in order to be represented as a basin wide measure. Identifying park space may be complicated and difficult in some cases because the information most likely exists only at the local level and would require a survey to collect.

Interpretation
The indicator is a simple representation of urban efficiency since higher density communities typically are lower in cost and less intrusive on the rest of the ecosystem. Thus, the higher the ratio of population per square kilometre of land the better in achieving overall urban efficiency and a less stressed ecosystem.

Comments
The indicator is also a good proxy for commercial and industrial sprawl since development patterns for this sector typically parallels that of residential development. The socio-economic paper of SOLEC '94 indicated the relative urban densities between the City of Toronto, Ontario and Chicago, Illinois. The SOLEC '96 Land Use paper also discussed at length the efficiency aspects of higher density through the report.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s):
SOLEC Grouping(s): **land use**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Land Conversion (Indicator ID: 7002)

Measure
Percent change in land use type, including agriculture, urban development, and forest, marsh or other natural cover.

Purpose
To assess the changes in land use within the Great Lakes basin, and to infer the potential impact of land conversion on Great Lakes ecosystem health.

Ecosystem Objective
Sustainable development is a generally accepted land use goal for Canadians and Americans. This indicator supports Annex 13 of the GLWQA.

Endpoint
Zero change would be sustainable but probably unrealistic, while reversion of other uses to the natural ecosystem would be desirable.

Features
High rates of land conversion place stress on the natural ecosystem and are typically associated with inefficient land use, such as urban sprawl. Population growth is a driver for more development which displaces both agricultural and natural lands. Other things being constant, high conversion rates are associated with rapid rates of urban sprawl which is economically inefficient and displaces natural land that serves other biological purposes in the ecosystem or agriculture which in turn may convert land from natural uses. The conventional pattern of land conversion has been for urban growth to displace agricultural lands which, in turn, expand into remaining lands. Urban development also expands into natural lands.

Illustration
The indicator allows easy and visual interpretation of land use changes and trends. Land conversion is an evolutionary process and this indicator will be displayed as a graphical representation of land use by category in the basin.

Limitations
This indicator provides a measurement of the conversion of the land use type, but not of the change in quality of the land use. For example, conversion of a highly intensive, chemical-intensive agriculture area to an urban area, particularly one that is well-planned and utilizes environmental and resource conservation management plans, may result in less stress to the ecosystem. Also, urban development on excavated, landfill or other contaminated sites may also be positive changes.

Interpretation
Generally, land that converts from natural to agricultural and from natural and agricultural uses to developed uses is undesirable. Conversion back to natural uses would be desirable.

Comments
SOLEC '96 represented the rate of land converted from agriculture to developed urban uses. Clearly, loss of agricultural land in the basin places pressure on other lands such as forests and wetlands to be placed into agricultural uses. Satellite imagery might be useful in detailing the changes over time of the urban frontier actually developed and this indicator.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s):
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Brownfield Redevelopment (Indicator ID: 7006)

Measure
Total acreage of redeveloped brownfields.

Purpose
To assess the acreage of redeveloped brownfields, and to evaluate over time the rate at which society rehabilitates and reuse former developed land sites that have been degraded by poor use.

Ecosystem Objective
Sustainable development is a generally accepted goal for North American society.

Endpoint
Elimination of all brownfield sites.

Features
"Brownfields" are abandoned, idled, or under-used industrial and commercial facilities where expansion, redevelopment, or reuse is complicated by real or perceived environmental contamination. Some of the sites contain underground storage tanks; others have contaminated soils from industrial waste or manufacturing byproducts. Still others may possess no contamination at all, but the fear of contamination nonetheless scares prospective buyers and lenders away. This creates an incentive for development to occur in pristine, undeveloped areas.

The indicator would describe trends in brownfields redevelopment and urban renewal, including areas that technically can not be described as brownfields. The indicator is a measure of the rate at which society is employing former contaminated (typically industrial) sites to new and more environmentally compatible uses. Brownfields reuse offers an opportunity to reduce pressure on the ecosystem by slowing the rate of land conversion and typically increasing urban densities. An inventory of contaminated sites is maintained by most provincial and state and federal governments, although a broader definition would require municipal involvement. The goal is to redeploy all of these lands as soon as possible.

Illustration
The total number of identified acres of outstanding brownfield sites throughout the basin by state/province and lake basin. Bar graphs could be used to demonstrate changes over time.

Limitations
The identification of brownfield sites is limited by the availability of information on vacant and redeveloped sites. Data for this indicator may not reveal an accurate trend in brownfield redevelopment, particularly if redevelopment on brownfield sites results in another use that causes further land contamination.

Interpretation
Reducing the number of acres/square kilometres of brownfield sites can be seen as a positive development in the basin. Increasing brownfield inventories not only indicate challenges of dealing with contaminated sites but also opportunities for redevelopment.

Comments
Numerous examples are available including one site in Detroit that has been converted to a public park. Others are typically reduced as urban housing or clean industrial use.

The achievement of the end point will depend on the opportunities available for new land uses as an alternative to land conversion.

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Mass Transportation (Indicator ID: 7012)

Measure
Percent of commuters using public transportation.

Purpose
To assess the percentage of commuters using public transportation, and to infer the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and pollution creation.

Ecosystem Objective
Sustainable development as interpreted by Canada and the U.S. through ongoing efforts of agencies, such as the Canadian National Roundtable on Environment and Economy, and more specifically pollution related as recognized in Annex 15 of the GLWQA.

Endpoint
A ratio over 50% would be desirable.

Features
The indicator is a simple measure of the average number of commuters using public (mass) transit in urban centres throughout the basin. It is valuable in recognizing the socio-economic costs associated with urban form that contributes to highly energy intensive, highly polluting, non-productive and time wasting urban commuting. The indicator could be aggregated and used as a basin wide indicator. Data are typically collected by survey and may vary from community to community and with respect to periodicity.

Illustration
The indicator is represented graphically by a ratio of daily working commuters that use public transit options including rail and road mass transit options.

Limitations
The indicator is a proxy for efficiency of an urban community. It focuses only on work commuters as data is not available for other commuting purposes, such as recreation. Finally, not all public transit may be more efficient than the use of private automobiles, for example, empty buses running on low density suburban streets.

Interpretation
Use of public transit for commuting in urban communities is typically more efficient than the private automobile. Less energy is required, less pollution created, more land can be dedicated to living/working space and less to unproductive roads and parking lots, less working and non-working time is wasted behind the wheel of a car, and the costs to the community are reduced by higher levels of urban transit use.

Comments
Reducing the amount of time and the cost of travelling for work and pleasure will impact on total resource use in society as well as reducing the amount of unproductive time spent commuting to work and increasing recreational time. Greater adoption of mass transportation involves changes in urban development patterns as well as lifestyle. The former City of Toronto, with a relatively dense and compact urban form had a relatively high level of mass transportation. That level fell considerably when the City expanded its municipal boundaries to include more suburban areas.

Private vehicle commuter traffic is responsible for a significant amount of current smog in cities and is a major contributor to global climate change through the emission of large quantities of greenhouse gases derived from non-renewable sources.

This is only a proxy measure of the efficiency of goods transportation.

Unfinished Business
- Need to determine the time-scale of indicator. For example, will the measurements provided for this indicator be taken on an annual basis? A biennial basis?...
- Need to determine how the indicator will be presented? For example, this indicator could show trends in use of mass transit over time using a bar graph with percentage of commuters using public transportation on the y axis and years on the x axis.
- Need to add a discussion related to understanding the trends presented by the indicator. For example, what baseline will be used to determine if 50 percent of commuters are using public transportation?

Relevancies

Indicator Type: pressure
Environmental Compartment(s): air, land
Related Issue(s): climate change, stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 11: Surveillance and monitoring, 15: Airborne toxic substances
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 24, 2000

Sustainable Agricultural Practices (Indicator ID: 7028)

Measure
Number of Environmental and Conservation farm plans in place.

Purpose
To assess the number of Environmental and Conservation farm plans, and to infer environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Ecosystem Objective
This indicator supports Annexes 2, 3, 12 and 13 of the GLWQA.

Endpoint
Sustainable agriculture through non-polluting, energy efficient technology and best management practices for efficient and high quality food production.

Features
Given the key role of agriculture in the Great Lakes ecosystem, it is important to track changes in agricultural practices that can lead to better ecological integrity in the basin. The indicator identifies the degree to which agriculture is becoming more sustainable and has less potential to adversely impact the Great Lakes ecosystem. Integrated pest management and zero till soil management are typically part of an environmental farm management plan. It is expected that more farmers will embrace environmental planning over time.

Illustration
The total number of farm environmental plans (or ecological plans) that are in place as a percentage of the total number of farms in the basin.

Limitations
Plans vary from jurisdiction to jurisdiction and thus may lack consistency in terms of completeness of agricultural sustainable practices. In addition there is no standard way of knowing the state of implementation of these plans.

Interpretation
Having an environmental management plan in place provides an incentive for farmers to commit to environmentally sound land use practices. The more plans in place the better. In future there may be a way to grade plans by impacts on the ecosystem. The first year in which this information is collected will serve as the base line year.

Comments

Unfinished Business
- This indicator requires much further development and refinement. Specific consideration will be given to assessing the use of conservation tillage, buffer strips and herbicide application.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources
IJC Desired Outcome(s): 8: Absence of excess phosphorus, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Green Planning Process (Indicator ID: 7053)

Measure
Number of municipalities with environmental and resource conservation management plans.

Purpose
To assess the number of municipalities with environmental and resource conservation management plans in place, and to infer the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation and natural area preservation.

Ecosystem Objective
Sustainable development is a goal of North American society. This indicator supports Annex 13 of the GLWQA.

Endpoint
All municipalities should have an environmental and resource conservation plan.

Features
The indicator is an acknowledgment that municipalities with environmental and resource conservation management plans require resource conservation as a mandatory part of the municipal land use decision process. Ideally all municipalities in the basin will focus on limiting urban sprawl; incorporating a preference for high density, redevelopment and brownfield utilization; conserving of natural features and resources, such as natural watercourse retention and woodlot preservation; and promoting mass transit. Once a development plan (i.e., a plan submitted by developers for new development) has been approved, it is safe to assume that it has taken account of environmental considerations.

Illustration
The indicator will be a numerical ratio of municipalities that do have plans out of the total number of municipalities in the basin. This could be presented by maps or through simple numerical ratios.

Limitations
This indicator will provide a measurement of the number of green plans in place, but will not assess the quality of the plans or if they are being implemented.

Interpretation
An increasing number of plans over time represent a positive trend. The indicator will be used to determine improvements over time as more municipalities undertake to develop and implement these plans. Data collected during the first year will serve as a baseline.

Comments
Oakland County Michigan has a detailed provision that all developers must follow in order to develop their lands.

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): water, land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**, societal
GLWQA Annex(es): 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

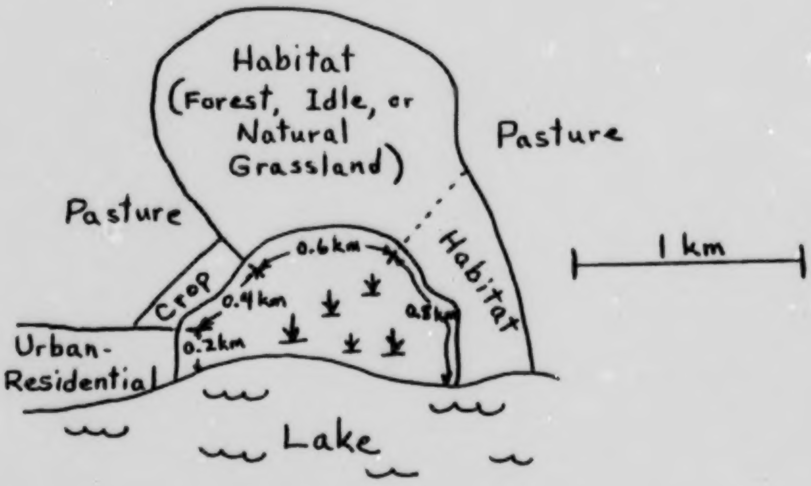
Last Revised
Feb. 24, 2000

Habitat Adjacent to Coastal Wetlands (Indicator ID: 7055)

Measure

Land use adjacent to a representative set of coastal wetlands, measured as a weighted score determined by multiplying the wetland perimeter (km) in each land use by an associated weighting factor and dividing by the total upland perimeter (km) of the wetland. Weighting factors depend on the width of habitat (wooded, idle or natural grassland cover) directly abutting the wetland and on the land use adjacent to that habitat, as shown below:

Habitat Width Adjacent to Wetland	Land Use Adjacent to Habitat		
	Urban/Residential	Row Crop	Hay/Pasture
>750 m	1	1	1
250 - 750 m	0.25	0.5	0.8
50 - 250 m	0.1	0.2	0.5
20 - 50 m	0.05	0.1	0.25
<20 m	-1.0	-0.5	-0.2



$$\text{Score} = \frac{((0.2\text{ km})(-1) + (0.4\text{ km})(-0.5) + (0.6\text{ km})(1) + (0.8\text{ km})(0.8))}{(0.2\text{ km}) + (0.4\text{ km}) + (0.6\text{ km}) + (0.8\text{ km})}$$

$$= \frac{(-0.2\text{ km}) + (-0.2\text{ km}) + (0.6\text{ km}) + (0.64\text{ km})}{2.0\text{ km}} = 0.42$$

Purpose

To provide an index of the quality of adjoining upland habitat which can have a major effect on wetland biota, many of which require upland habitat for part of their life cycle.

Ecosystem Objective

To maintain and restore healthy coastal wetlands and associated diverse wildlife populations which require adequate adjoining upland habitat (GLWQA Annexes 2 and 13).

Endpoint

Score for Habitat Adjacent to Coastal Wetlands = 1 (corresponding to all wetlands with adjacent habitat >750 m).

Features

This is an indicator of off-site influence, and assesses the effects of land uses adjacent to coastal wetlands. It is potentially linked to all of the Coastal Wetland State/Response indicators. Although related to indicator 8132, Nearshore Land Use, and to indicator

8136, Nearshore Natural Land Cover, its specificity to wetlands makes it much more relevant to wetland health. It will show steady trends rather than high variability.

Illustration
A graph will be displayed with x-axis as years and y-axis as adjacent habitat ranging from a worst case (all wetlands with adjacent urban uses) of -1 to a best case (all wetlands with > 750 m of adjacent habitat) of 1.

Limitations
This indicator is a direct measure of habitat for only a subset of coastal wetlands. This subset should represent wetland types, adjacent habitat, and land uses. Weighting factors are best estimates rather than based on precise science, but can easily be amended and applied to past data. Like several wetland indicators, it depends on availability and utility of remote sensing for the representative set. Interpretation, although straightforward, will take some time.

Interpretation
The lower the weighted average, the worse the ranking.

Comments
Among coastal ecosystems, the integrity of coastal wetlands is particularly dependent on adjoining habitat. Many wetland biota need non-wetland habitat for part of their life cycle, with varying area and distance requirements. The quality (e.g., disturbance, surface water quality) of adjoining habitat is in turn influenced by its abutting land use. This indicator uses simple scores to quantitatively rank these relationships.

This Indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected. Also, each site can be individually scored for local interest.

Unfinished Business

Sorting
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): coastal wetlands, nearshore terrestrial, **land use**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environment integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Habitat Fragmentation (Indicator ID: 8114)

Measure

The pattern of natural habitat remaining within ecoregions/subsections, as measured by 1) area to perimeter ratio; 2) habitat patch size; and 3) percent intact cover.

Purpose

To assess the amount and distribution of natural habitat remaining within Great Lakes ecoregions, and to infer the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

Ecosystem Objective

Each LaMP is likely to contain objectives that address maximizing the amount of land cover adjacent to the lake. This indicator supports Annex 2 of the GLWQA.

Endpoint

The Framework on Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (Environment Canada et al, 1998) suggests specific marsh and forest patch sizes that are required to support various species. For example, 200 hectares of forest patch is required for successful interior forest bird breeding. A total area with more than 70% intact cover is needed for birds.

Features

This indicator will present trends in remaining natural habitat within ecoregions/subsections over time. Sufficient parcels of natural habitat are necessary to support wildlife activities such as breeding and migration. For example, lack of interior forest habitat adversely impacts the reproduction of breeding birds. Loss of natural habitat also adversely impacts migrating birds that need to touch down to refuel on their treks north and south. For some threatened species, there is insufficient habitat to sustain populations.

Illustration

Using GIS, habitat patch size and percent intact cover can be graphically displayed on a map. Calculations to determine area to perimeter ratio could be done on a GIS using a specially designed algorithm. Although illustrating area to perimeter ratio is more difficult, it would be possible to highlight all patches with a desirable ratio on a GIS map once calculations are complete.

Limitations

Although "intact cover" most likely means natural vegetation, primarily forest, there is a need to define this term. The relationship, for example, between the three endpoints — percent intact cover, patch size and perimeter to area ratio — and bird breeding is better understood than the relationship between the endpoints and bird migration. A better understanding of how these endpoints affect bird migration is necessary.

Interpretation

Additional research is needed to understand how much habitat is required in a particular ecoregion for different species and for different functions.

Comments

As suggested, the amount of habitat required for breeding birds is known, but less is known about the amount of natural vegetation required for migrating birds. The requirements for other species will be just as challenging. Information for this indicator can be collected using remote sensing products.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): land use
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Contaminants in Recreational Fish (Indicator ID: 113)

Measure
Concentration of PBT chemicals in the catch-weighted average, edible tissue of recreational fish.

Purpose
This indicator will assess the levels of PBT chemicals in fish, and it will be used to infer the potential harm to human health through consumption of contaminated fish.

Ecosystem Objective
Fish should be safe to eat. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint

Features
This indicator will be used to monitor fluctuations in the concentration of contaminants in the average fish from each Great Lake. The average fish concentration is defined as the average PBT concentration for each fish-species weighted by the proportion of that species' mass caught in each Great Lake. Estimation of this index entails no new sampling or analytical costs. Catch records, by species, are available from the Great Lakes Fishery Commission. Concentrations of contaminants in dominant fish species are collected by several of the States and the Ontario Ministry of the Environment. This index will be calculated every two years based on best available data and appropriate statistical methods. To make calculation of the index manageable, uncommon species – those making up less than 5% of the total catch by weight – will not be considered. To account for cooking losses and the fact that most consumers skin their fish or do not eat skins, final PBT concentrations (except for mercury) in fillets with skins will be multiplied by 50%.

Illustration
The calculated average will be depicted on simple bar graphs showing the fluctuation of PBT concentrations in the average fish over time and space. As reduction in chemical concentrations is an exponential process, time trends should be depicted on a logarithmic Y-axis. Average concentrations will be depicted with tissue guidelines for consumption advisories to illustrate the average consumability, according to existing advisory standards, of the recreational fish from each Great Lake.

Limitations
This indicator pertains to the representative fish catch of recreational anglers from the Great Lakes. This index specifically should not be used to assess risk to populations that consume fish species that have PBT concentrations that are higher or lower than average.

Interpretation

Comments
To understand the magnitude of a risk, citizens and regulatory personnel need to know risks posed to the average consumer as well as those pertaining to the most-exposed, most sensitive sub-groups. As opposed to estimators of worst-case exposure, average fish concentrations are unbiased indicators. As indicators of central tendency, average concentrations are necessary to estimate likely risks and risks to the population as a whole.

Unfinished Business
- Need to determine the specific PBT chemicals that will be measured.
- Need to define the ecosystem objective to be referenced.
- Need to define/develop endpoints. Will action levels be used as reference?

Relevancies
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

Last Revised
Feb. 24, 2000

E. coli and Fecal Coliform Levels in Nearshore Recreational Waters (Indicator ID: 4081)

Measure
1) Counts of *E. coli* and/or fecal coliforms (FC) in recreational waters measured as number of organisms per volume of water (e.g., FC/ml); and 2) frequency of beach closings at specific locations.

Purpose
To assess *E. coli* and fecal coliform contaminant levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and to infer potential harm to human health through body contact with nearshore recreational waters.

Ecosystem Objective
Waters should be safe for recreational use. Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. This indicator supports Annexes 1, 2 and 13 of the GLWQA.

Endpoint
E. coli and fecal coliform levels should not exceed national, state, and/or provincial standards set for recreational waters.

Features
One of the most important factors in nearshore recreational water quality is that it be free from microbial contamination. Recreational waters may become contaminated with animal and human feces from sources and conditions such as combined sewer overflows that occur in certain areas after heavy rains, agricultural run-off, and poorly treated sewage. This indicator will track *E. coli* and fecal coliform abundance and the frequency of beach closings over time and across geographic locations throughout the basin. Analysis of data may show seasonal and local trends in nearshore recreational waters. The trends provided by this indicator will aid in beach management and in the prediction of episodes of poor water quality.

Illustration
For each site selected throughout the basin, a bar graph will be presented showing the counts of *E. coli* and fecal coliform over several years. Statistical analysis will be used to examine the temporal and spatial trends in water quality in recreational beach areas. Data will be presented as a bar graph or as a GIS map showing the number of beach closings over time.

Limitations
Variability in the data from year to year may result from the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. In addition, variability of weather from year to year may also affect the variability in bacterial counts. Viruses and parasites, although a concern in recreational waters, are difficult to isolate and quantify at present, and feasible measurement techniques have yet to be developed. Comparisons of the frequency of beach closings will be limited due to use of different water quality criteria in different localities.

Interpretation
This indicator will rely on national, state, and/or provincial *E. coli* or fecal coliform standards as a benchmark. Trends that demonstrate an increase in fecal pollution levels over time, and above the appropriate standard, will be considered negative, or bad, trends. Trends that demonstrate a decrease in fecal pollution levels over time, and below the appropriate standard, will be considered positive, or good, trends.

Comments
Analysis of data may show seasonal and local trends in recreational water. If episodes of poor recreational water quality can be associated with specific events, then forecasting for episodes of poor water quality may become more accurate.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water, biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): nearshore waters, human health
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 2: Swimmability, 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s): 10: Recreational water impairment

Last Revised
Feb. 24, 2000

Contaminants in Edible Fish Tissue (Indicator ID: 4083)

Measure
Concentration of PBT chemicals targeted by the GLWQA in edible fish tissue.

Purpose
To assess the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and to infer the potential exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

Ecosystem Objective
Fish in the Great Lakes ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint
Reduction in concentration of PBT chemicals in fish tissue to levels that do not pose a risk to populations consuming Great Lakes fish. The elimination of fish advisories in the Great Lakes may be considered to be an appropriate endpoint.

Features
The temporal and geographic trends in the chemical contaminant levels in fish species consumed by human populations in the Great Lakes basin will be used as an indicator of exposure to PBT chemicals. Concentrations of contaminants in fish should be determined from a boneless, skinless fillet of dorsal muscle flesh removed from the fish. This would provide not only the most consistent test results, but is also the most edible portion of the fish. Choosing appropriate indicator species is crucial and should be based on fish consumption patterns and availability of data. Additional chemicals can be considered as new information arises. The indicator will allow regulatory agencies to make suggestions regarding remedial planning as well as issuing advisories to the public on safe consumption limits.

Illustration
Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space.

Limitations
Data for use in developing indicators exist, however, there are differences in surveillance techniques for fish consumption and differences in tissue sampling methods between jurisdictions.

Interpretation
Reductions in contaminant levels in fish tissue will reflect an improvement in environmental quality and the potential for reduced exposure to contaminants from consumption of Great Lakes fish.

Comments

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

Last Revised
Feb. 24, 2000

Chemical Contaminant Intake from Air, Water, Soil and Food

(Indicator ID: 4088)

Measure

Estimated total daily intake of PBT chemicals targeted by the GLWQA from air, water, soil, and food sources.

Purpose

To estimate the daily intake of PBT chemicals from all sources, and to evaluate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Ecosystem Objective

This indicator supports Annex 12 of the GLWQA.

Endpoint

Intake of PBT chemicals from all sources should be below established guideline values and should continue to decline.

Features

This indicator tracks contaminants levels in various media and their estimated daily intake via ingestion and inhalation. Daily intakes have been estimated for the following age groups : 0 - 0.5 years, 0.5 - 4 years, 5 - 11 years, 12 - 19 years, 20 + years, and total lifetime, using available data up to 1996 (Great Lakes Health Effects Program, Health Canada). Estimated daily intakes can be updated periodically, as new data becomes available.

Illustration

The temporal variation in estimated dose for each age group and the relative contribution of each media as a percentage of total dose will be displayed in a graphic format.

Limitations

Factors such as technological advances, differences in sampling and laboratory procedures, as well as survey questionnaires, create difficulties in accurately comparing historical data.

Interpretation

Changes in the estimated daily dose from air, water, soil or food sources will indicate changes in environmental quality, in human exposure, and the risk to human health.

Comments

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): humans
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 24, 2000

Drinking Water Quality (Indicator ID: 4175)

Measure
Concentrations of chemical substances such as metals (e.g., lead, mercury) and other inorganic compounds, pesticides, radionuclides, and drinking water disinfection by-products (e.g., trihalomethanes) as well as microbial parameters such as bacteria, viruses and parasites in raw, treated and distributed drinking water.

Purpose
To assess the chemical and microbial contaminant levels in drinking water, and to evaluate the potential for human exposure to drinking water contaminants and the efficacy of policies and technologies to ensure safe drinking water.

Ecosystem Objective
Treated drinking water supplies should be safe to drink. This indicator supports Annexes 1, 2, 12 and 16 of the GLWQA.

Endpoint
Densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances should not exceed human health objectives, standards, or guidelines.

Features
This indicator would reveal trends in contaminant levels in raw, treated and distributed water in various locations throughout the basin. Through existing water monitoring programs, which analyse raw, treated and distributed waters, results can be compared against established water quality objectives. This evaluation applies to water supply systems that draw water from either surface water or groundwater sources. Data on temporal trends, such as seasonal differences or changes over time, in chemical or microbial contaminant concentrations for specific locations could be identified.

Illustration
For selected locations in the Great Lakes basin, simple bar or line graphs would display the average concentration of contaminants in raw, treated and distributed water. The data could also be displayed in a GIS format that would allow for a variety of endpoint analyses to be displayed as an overlay on maps of the entire Great Lakes basin or more local areas.

Limitations
Most contaminants in drinking water rarely exceed guidelines and many are below their analytical detection limit. Since the absolute concentration of some contaminants may not be determinable, it is difficult to show fluctuations in their concentration levels.

Interpretation
Existing monitoring programs at drinking water treatment plants analyze for chemical and microbial contaminants in raw, treated and distributed waters. Results can be compared against established water quality guidelines and objectives. The data could be supplemented with additional information showing relationships between contaminant levels and human health risks; for example, the association between long-term exposure to chlorination disinfection by-products in drinking water and the increased risk of bladder and colon cancers.

Comments

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens, nutrients
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 16: Pollution from contaminated groundwater
IJC Desired Outcome(s): 3: Drinkability, 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s): 9: Restrictions on drinking water consumption or taste and odor problems

Last Revised
Feb. 24, 2000

Air Quality (Indicator ID: 4176)

Measure

Concentration of chemicals and particulate matter in ambient air.

Purpose

To monitor the air quality in the Great Lakes ecosystem, and to infer the potential impact of air quality on human health in the Great Lakes basin.

Ecosystem Objective

Air should be safe to breathe. Air quality in the Great Lakes ecosystem should be protected in areas where it is relatively good, and improved in areas where it is degraded. This is consistent with ecosystem objectives statements being adopted by certain lakewide management plans, including Lake Superior, (Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior, Lake Superior Binational Program, 1995), in fulfilment of Annex 2 of the Great Lakes Water Quality Agreement. This indicator also supports Annexes 1, 13 and 15.

Endpoint

Canadian and U.S. air quality standards.

Features

The Great Lakes basin experiences high levels of certain air pollutants due to both local sources and long range transport. Studies conducted in the Great Lakes region have provided strong evidence linking ground-level ozone and sulphates to increased rates of hospital admissions for cardiorespiratory disease and to increased death rates. Pollutants that can be used to assess overall air quality include SO_2, CO, O_3, NO_x, TRS and SP. Air toxics, such as benzene, formaldehyde, and ethylene dichloride, should also be used to assess air quality. Other air pollutants can be added as new information becomes available. This indicator can use information from existing air monitoring databases. Data can be supplemented with established associations between levels of ambient air pollution and rates of admissions to acute care hospitals for cardiorespiratory disease.

Illustration

Using a GIS mapping display, trends in pollutant levels over several years for each pollutant in a particular region or over the entire Great Lakes basin data could be presented. Data could also be displayed as the number of exceedances of guidelines which may be established for any pollutant. The above data could be supplemented with additional graphs showing the relationships between sulphate and ozone levels in outdoor air and hospital admissions for cardiorespiratory diseases.

Limitations

Canadian and U.S. jurisdictions employ different standards for measurement of exceedances.

Although indoor air is a major contributor to exposure to air toxics, there is no practical way to consistently monitor indoor air quality. Therefore, this component to the estimate of total exposure to airborne contaminants will not be included in this indicator.

Interpretation

Interpretation of the indicator would be made by identifying trends in the levels of air contaminants over time in comparison to guideline levels.

Comments

A significant association is found between atmospheric ozone and sulphate levels and the number of daily hospital admissions for respiratory conditions. Five percent of daily respiratory admissions in the months of May to August can be attributed to ozone, and an additional 1% to sulphates. This finding is consistent among all age groups. The largest impact appears to be on children under 2 years of age, in whom 15% of respiratory hospital admissions are attributed to ozone and sulphate together, while the elderly are least affected (4%). There does not appear to be a level of ozone below which no adverse respiratory health effects are observed.

For both respiratory and cardiac illnesses, the average daily hospitalization rates increase with increasing levels of sulphates. A 13 ug/m^3 increase in sulphates recorded on the previous day is associated with a 3.7% increase in respiratory admissions and a 2.8% increase in cardiac admissions. Admissions for cardiac diseases increases 2.5% for those under 65 years and 3.5% for those 65 years and older.

Some air pollution emissions can be prevented through better pollution prevention or by changing the demand for certain products and services that contribute to air pollution. Therefore, this indicator can additionally measure progress on sustainable development by determining the degree to which resources are wasted as pollution, thereby representing inefficiency in human economic activity.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): air
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources, 15: Airborne toxic substances
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 24, 2000

Chemical Contaminants in Human Tissue (Indicator ID: 4177)

Measure
Concentrations of PBT chemicals targeted by the GLWQA in human tissues such as blood, breast milk, hair, urine and adipose tissues.

Purpose
To assess the concentration of PBT chemicals in human tissues, and to infer the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

Ecosystem Objective
This indicator supports Annexes 1, 12 and 17 of the GLWQA.

Endpoint
Continued reduction of PBT chemical concentrations in human tissue. Where PBT chemicals are detected, they should be maintained below health guidance levels.

Features
This indicator will monitor the concentration of PBT chemicals in human tissues (both general and at-risk populations) to establish geographic patterns and trends over time, providing an estimate of both past and current chemical exposures.

Illustration
Data will be displayed as bar graphs showing PBT chemical concentrations over time to highlight trends and in GIS format to illustrate geographic patterns in body burden levels.

Limitations
This indicator requires extensive sampling of human populations, as well as standardized tissue collection and chemical analysis methods for use by participating laboratories. A detailed history of the sample population, including diet, lifestyle, and occupation, is necessary to characterize the history of exposure.

Interpretation
The long persistence of PBT chemicals in the body would indicate that there is a relatively long time period between reductions in exposure and subsequent reductions in tissue levels. However, trends that demonstrate a decrease in the concentration of PBT chemicals in human tissue, to levels below health guidance levels, would be a positive indication that the human health risks posed by exposure to environmental contaminants are being reduced. Tissue levels above health guidance values are a concern for human health.

Comments
The body burdens of some PBT chemicals in at-risk populations around the Great Lakes and St. Lawrence basins can be 2 to 4 times greater than the general population.

Ref. Johnson et al., 1998. Public Health Implications of Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins. J. Great Lakes Res. 24(2):698-722.

Health Canada, 1998. Health-Related Indicators for the Great Lakes Basin Population: Numbers 1 to 20. Minister of Public Works and Government Services Canada.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): humans
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 15, 2000

Radionuclides (Indicator ID: 4178)

Measure

Concentration of Cs-137 and Sr-90 in cow's milk, gross beta activity in air and precipitation, and airborne and waterborne radionuclide emissions from nuclear power plants in the Great Lakes basin.

Purpose

To assess the concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and to estimate the potential for human exposure to artificial radionuclides.

Ecosystem Objective

This indicator supports Annexes 1 and 17 of the GLWQA.

Endpoint

Limit releases of artificial radionuclides to minimize human exposure.

Features

This indicator will provide a measure of the overall exposure of the Great Lakes basin population from nuclear weapons fallout. It will present almost 30 years of data on the concentration of cesium-137 and strontium-90, two types of radionuclides associated with above ground nuclear weapons testing, in cow's milk and gross beta activity in air and precipitation since cessation of atmospheric weapons testing. This indicator will also present trends in the concentrations of airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, providing an estimate of exposure to contaminants from nuclear power plant discharges. Measurements of radionuclide emissions may allow for the estimation of human exposure to discharges by nuclear power plants and may indicate geographical differences in exposure from those sources. In addition to natural background radiation, the Great Lakes basin contains nearly all components of the nuclear fuel cycle, as well as many radioisotope users such as hospitals and industry.

Illustration

Graphs will display almost 30 years of data on the concentration of cesium-137 and strontium-90 in cow's milk and gross beta activity in air and precipitation. Graphs will also present reported airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, beginning in 1972 (IJC Nuclear Task Force, 1997).

Limitations

Monitoring of radionuclides in the Great Lakes basin meets primarily the compliance needs of licenses for discharge. Very little of the current monitoring activities are designed to address, or are capable of considering, the movement and cycling of radionuclides through environmental compartments and ecosystems. The data for Cs-137 and Sr-90 concentrations collected during the past 30 years show a decline in radioactivity in the Great Lakes basin after the ban on above ground nuclear weapons testing. The trend illustrated by these data — decreased exposure to Cs-137 and Sr-90 due to decreased weapons testing — is not especially useful to policy makers and regulatory agencies.

Interpretation

A trend of decreasing concentration of artificial radionuclides over time would indicate a reduction in risk to human health. A trend of increasing concentrations would indicate a potential for greater human exposure.

Comments

Hypothetical estimates based on conservative exposure models estimates the total number of fatal cancers, non-fatal weighted cancers, and hereditary disorders over the lifetime of the current Canadian Great Lakes basin population attributable to a 50-year exposure to natural background radiation is of the order of 340,000. The total number of health effects attributable to radioactive fallout from all the weapons tests to date would be in the order of 5,000. Health Effects due to 50 years of operation of the nuclear fuel cycle at current levels would be of the order of 200. (Health Canada, 1997). On average, natural radiation accounts for more than 98% of human exposure to ionizing radiation, excluding medical exposures.

Health Canada. 1997. State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin. Minister of Public Works and Government Services Canada, Catalogue No. H46-2/97-214E.

International Joint Commission. 1997. Inventory of Radionuclides for the Great Lakes. Nuclear Task Force.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water, biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Geographic Patterns and Trends in Disease Incidence (Indicator ID: 4179)

Measure
Disease incidence rate (rate = number of new cases of specific disease/ size of population) for those diseases that have a demonstrated environmental link, such as cancers and birth defects, in the Great Lakes basin.

Purpose
To assess geographic and temporal patterns in disease incidences in the Great Lakes basin population, and to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.

Ecosystem Objective
This indicator relates to Annex 17 of the GLWQA.

Endpoint
Disease incidence rates should decrease over time. Environmental pollutants should be minimized as health risk factors.

Features
This indicator provides geographical and temporal patterns of disease incidence, such as cancer and birth defects, throughout the Great Lakes basin. Although cause and effect relationships cannot be established from this indicator, it is useful for identifying areas that may require investigation.

Illustration
This indicator is represented by maps of the Great Lakes basin illustrating the distribution of disease incidences, such as cancers and birth defects, in Ontario. In addition, a graph will show trends in the incidences of diseases over time.

Limitations
The accuracy of this indicator depends on the availability and quality of hospital records and continuing improvements of registry databases. Cause and effect relationships between environmental conditions and disease incidence rates cannot be established from this indicator. The explanation of disease incidence rates, such as cancer and birth defects, in any area requires more extensive epidemiological research to assess the relative importance of various factors, including diet, lifestyle, occupation, and exposure to environmental contaminants.

Interpretation
Although cause and effect relationships between environmental contaminants and disease cannot be established from this indicator, it is useful for identifying areas which require investigation. Additional evaluation will be required to refine the analysis to specific cancers and birth defects that are most likely to be related to environmentally related. This indicator may also allow for the development of new hypotheses regarding the role of environmental exposure in the etiology of human disease.

Comments
This indicator could be expanded in the future to include biomonitors of exposure, biomarkers of pre-disease conditions, endocrine disruption, and low birth weight.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): humans
Related Issue(s):
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Capacities of Sustainable Landscape Partnerships (Indicator ID: 3509)

Measure

Number of partnerships; basin location and geographic coverage; budgets, FTE staff; identification of major projects and initiatives.

Purpose

To assess the organizational capacities required of local coalitions to act as full partners in ecosystem management initiatives, including the enumeration of public-private partnerships relating to the pursuit of sustainable ecosystems through environmental management, staff, and annual budgets.

Ecosystem Objective

A Sustainable Great Lakes Ecosystem.

Endpoint

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features

Identification and survey of Sustainable Landscape Partnerships and a compilation of responses.

Illustration

Graphs, charts, narrative descriptions, and maps; data presented for the Great Lakes basin and cross-broken by individual Lakes; maps indicating coverage of basin(s) by stated partnership boundaries.

Limitations

Some interpretation of definitions is required to set qualifying criteria for sustainable landscape partnerships to determine the sample frame for the survey.

Interpretation

This indicator will show the coverage of the basin(s) by place-based ecosystem management initiatives and provide descriptive information of their capacities to do this work.

Comments

Local collaborative partnerships have the potential to address ecosystem issues that have proven beyond the capacities of existing resource management programs. These issues include such landscape wide objectives as habitat protection, non-point pollution, aesthetics, and recreational opportunities. Partnerships may include many actors who have not traditionally seen themselves as significant or important ecosystem managers. These potential partners may include land use and development decision makers, municipal governments, private industries, agriculture, engineering firms, universities, non-profit organizations, community foundations, and others.

Unfinished Business

- This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

Relevancies

Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): societal
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

October 20, 1999

Organizational Richness of Sustainable Landscape Partnerships (Indicator ID: 3510)

Measure
The diversity of the members participating in partnerships measured on two axes: Horizontal Integration – the diversity of local partners; and Vertical Integration – the direct participation of federal and state/provincial actors in local partnership initiatives.

Purpose
to assess the diversity of membership and expertise included in partnerships. Horizontal integration is a description of the diversity of partnerships required to address local issues, and vertical integration is the description of federal and state/provincial involvement in place-based initiatives as full partners.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Horizontal Integration: Measured by surveying identified partnerships as to the range and diversity of participants engaged in full partnership.
Vertical Integration: Measured by surveying identified partnerships as to the collaborative involvement of federal and state/provincial actors as full partners in local initiatives.

Illustration
Graphs, charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "full partners" and to translate the diversity of partners into a simple scalar presentation for each locality and basin.

Interpretation
The description of the base capacities of partnerships to accomplish sustainable landscape initiatives by building collaborative relations between local decision making systems, e.g., the land conversion system: lending institutions, developers, and real estate agents; the description of the extent of participation of federal and state/provincial partners to enhance and empower these local initiatives.

Comments
Ecosystem management initiatives require new constituencies that expand the traditional boundaries of resource management. In addition, Federal, state/provincial, and regional agencies have the greatest expertise and resources to support sustainable ecosystem management. Their presence as full partners in local initiatives brings their expertise and resources to the table to assist in achieving shared goals.

Unfinished Business
- This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): societal
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
October 20, 1999

Integration of Ecosystem Management Principles Across Landscapes (Indicator ID: 3511)

Measure

Simple reporting of the adoption of ecosystem management as a guiding principle in place-based resource management programs by states/provinces and regional agencies and governments and budget allocations in support of ecosystem management programs and projects.

Purpose

To describe the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted ecosystem management guiding principals in place-based resource management programs.

Ecosystem Objective

A Sustainable Great Lakes Ecosystem

Endpoint

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features

Survey of basin and lake governments to identify policies, programs, and agencies for which ecosystem management is a guiding principle and budget allocations in support of these activities.

Illustration

Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations

Some definition and interpretation will be required to set parameters for "adoption of ecosystem management as a guiding principle."

Interpretation

The formal adoption of ecosystem management as an agency strategy combined with an description of the resources allocated for the implementation of the strategy provides a index of institutional commitment to stewardship initiatives.

Comments

Adoption of ecosystem management principles necessarily leads to the identification of interrelationships in landscape systems. An emphasis on these interrelationships requires the completion of ecological risk and functional value assessments as well as community value surveys to determine priorities pertaining to ecosystem health. This process leads to the definition of appropriate action in places.

Unfinished Business

- This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

Relevancies

Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): societal
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

October 20, 1999

Integration of Sustainability Principles Across Landscapes
(Indicator ID: 3512)

Measure
Simple reporting of the adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments and budget allocations in support of sustainability initiatives and projects.

Purpose
To describe the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted sustainability guiding principals in place-based resource management programs.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Survey of basin and lake governments to identify policies, programs, and agencies that have adopted place-based sustainability as a strategic goal and allocated resources for its achievement.

Illustration
Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments."

Interpretation
The formal adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments combined with a description of the resources allocated for its achievement provides a index of institutional commitment to stewardship initiatives.

Comments
Adoption of place-based sustainability principles establishes the balance between economic vitality, environmental health and social well being as a fundamental goal. It also institutionalizes a long term time horizon for ecosystem management activities. Focusing sustainability on landscapes will lead to the establishment of levels of integrity and health and an acknowledgment that functioning and inter-related systems are required to maintain this health and integrity.

Unfinished Business
- This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
October 20, 1999

Citizen/Community Place-Based Stewardship Activities (ID: 3513)

Measure

An enumeration and description of programs and projects that engage citizens in the stewardship of their landscapes / ecosystems and/or foster the ethic of stewardship; total number of identified programs, total number of participants, basin location.

Purpose

To reflect the number, vitality and effectiveness of citizen and community stewardship activities. Community activities that focus on local landscapes/ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a "sense of place."

Ecosystem Objective

A Sustainable Great Lakes Ecosystem

Endpoint

Continuing programs supporting a stewardship ethic and sense of responsibility for the landscapes within which people live. The building of a sense of place and the establishment of an identity for the local landscape including an understanding of the balance of interrelationships required to maintain the quality, health, and vitality of these landscapes over time.

A critical mass of local support for partnerships responsible for setting and maintaining levels of ecosystem health and integrity in places throughout the Great Lakes basin.

Features

Identification of place-based landscape/ecosystem education programs. Identification of place-based landscape/ecosystem festivals. Identification of other place-based Landscape/Ecosystem programs which engage citizenry in stewardship activities and/or support a stewardship ethic and sense of place.

Illustration

Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations

Some definition and interpretation will be required to set parameters for "programs and projects which engage citizens in the stewardship of their landscapes/ecosystems."

Interpretation

Measures activities that indicate citizen/community engagement and support for stewardship.

Comments

Community support for stewardship is required if governments, agencies, industry, and others are to adopt stewardship as a core value. In the case of some issues this support will be essential. For example, habitat protection will not be successfully addressed without the collaboration of local land use decision makers who have embraced the ethic of stewardship. The extent to which these local officials will actually respond to the need for habitat protection will be determined in part by the strength of the local constituency supporting stewardship as a community value.

Unfinished Business

- This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

Relevancies

Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

October 20, 1999

Aesthetics (Indicator ID: 7042)

Measure
Visible waste and refuse in communities around the basin.

Purpose
To assess the amount of waste and decay around human activities in the Great Lakes basin, and to infer the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

Ecosystem Objective
GLWQA Annex 2 requirement for aesthetics - cleanliness and freedom from evidence of waste.

Endpoint
Absence of obvious waste and decay around human activities and an obvious attention to cleanliness and respect for the environment.

Features
Aesthetics is an important aspect of society. It can relate to the management of other components of the ecosystem. Examples of poor aesthetics include waste oil and scum deposits in surface waterways, excessive trash along roadsides and on city streets, and run down and crumbling buildings within cities. The indicator is measured by a survey of waste and refuse that can be ascertained by a survey of communities in the basin. To determine the condition of aesthetics around the Great Lakes basin, surveys would need to be conducted to ascertain perspectives and opinions. This indicator is linked to other stewardship indicators, especially pollution prevention.

Illustration

Limitations
This indicator can be highly subjective although there is general agreement that obvious signs of waste and decay of private and public property are unaesthetic and signs of poor ecosystem management. The components of this indicator are not currently monitored since cleanliness and order can be highly subjective. Aesthetics should be kept in the context of waste or lack of maintenance and not become a matter or issue of taste and style.

Interpretation
This indicator represents a culture of maintenance and respect of the environment. A result approaching the endpoint indicates better care for the environment.

Comments
The level of order and cleanliness of a community, or other human activity (e.g., farm operation), can provide information on perspectives related to environmental health. Society has made no specific attempt to measure or comparatively evaluate this aspect.

Unfinished Business
- Need to determine how often the surveys would be conducted (i.e., what are the temporal trends this indicator would measure?).
- Need to determine how this indicator will be presented. For example, will a bar graph or a map be used?

Relevancies
Indicator Type: state
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s): 11: Degradation of aesthetics

Last Revised
October 20, 1999

Economic Prosperity (Indicator ID: 7043)

Measure
Unemployment rates within the Great Lakes basin.

Purpose
To assess the unemployment rates within the Great Lakes basin, and, when used in association with other Societal indicators, to infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

Ecosystem Objective
Human economic prosperity is a goal of all governments. Full employment is a goal for all economies and humans are part of the ecosystem.

Endpoint
Achieving the lowest economically sustainable unemployment levels possible. Levels of unemployment under 5% in western societies are considered full employment.

Features
The indicator demonstrates the economic ability of humans to avoid abusive behaviour of the rest of the ecosystem. In a global context, wealthier nations (US and Canada, Europe) are more likely to also have better environmental management regimes because they can better afford them and can afford to avoid many of the highly exploitive choices with respect to the environment. Data on employment rates are collected regularly and frequently throughout the basin. The unemployment rate is a better indicator than gross domestic production per capita for this purpose since it focuses on human ability to meet their own needs through income provision and not necessarily through undesirable environmentally activities. For example, the oil spill from the Exxon Valdez increased gross domestic production, although it had a minimal effect on employment rates.

Illustration
The indicator will be best represented by a chart showing trends over years.

Limitations
The collection and presentation of the indicator information is not limited. It was noted in the World Commission on Environment and Development report "Our Common Future" that although economic well being is associated with higher levels of resource consumption and environmental degradation, higher levels of economic development afford the ability to better manage the ecosystem and can constrain unsustainable resource exploitation.

Interpretation
This indicator is useful in defining the extent to which society is meeting only human need and should be presented in the context of the other ecosystem indicators. Decreasing trends in unemployment may not correlate to improvements in the condition of the Great Lakes ecosystem. For example, higher employment levels may lead to greater spending, which may cause environmentally undesirable consequences, such as new sprawl development.

Comments
Since unemployment is determined from those actually seeking work, this is a good indicator of the degree to which society's pursuit of economic prosperity is being met.

Currently unemployment rates in the U.S. are at almost historic lows. Although distribution of income may not be ideal, there is a sense that the human component of the ecosystem is better off than it was prior to this period. Arguments for excessive ecosystem exploitation can be countered as not being necessary.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s): **societal**
GLWQA Annex(es):
IJC Desired Outcome(s): 5: Economic viability
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
October 20, 1999

Water Withdrawal (Indicator ID: 7056)

Measure
Water use per capita in the Great Lakes basin.

Purpose
To assess the amount of water used in the Great Lakes basin per capita, and to infer the amount of wastewater generated and the demand for resources to pump and treat water.

Ecosystem Objective
Sustainable development is societal goal for the Great Lakes basin.

Endpoint
Resource conservation means reducing the amount of water that is used and the amount of wastewater that results from that water use. Current North American water use rates are in excess of 300 litres per day - reducing that by 50% is desirable and consistent with some European countries.

Features
The indicator provides a quantitative measure of the rate at which natural resources are being used. For example, high levels of water use results in considerable wastewater pollution, that results in degraded water quality, as well as increased demand for energy to pump and treat water. The indicator is a gross measure of water supplied through water supply facilities in a jurisdiction divided by the total number of people in the jurisdiction.

Illustration
The indicator will be displayed as the water use per capita in litres/capita within jurisdictions in the basin and the basin as a whole. The indicator is a measure of both residential and industrial/commercial water use.

Limitations
Data are readily abundant although it needs to be gathered in a consistent format. Ground water sources from private wells are excluded.

Interpretation
Water use symbolizes societal regard to resource use. North Americans, including those in the Great Lakes region, have very high rates of per capita water use compared with other developed nations, and reductions would result in reduced stress on the ecosystem. Water use is high and growing in places such as Toronto, in spite of efforts over the years to encourage water efficiency and conservation.

Comments
Canada and the United States are among the highest water using nations, per capita on the Earth.

Unfinished Business
- Need to add a discussion related to understanding the trends presented by the indicator. For example, will a baseline of "ideal" or "sustainable" water consumption rates need to be developed to determine if data collected on an annual basis (or another regular interval) reveals positive or negative trends in the amount of water consumed.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water, humans
Related Issue(s): stewardship
SOLEC Grouping(s): land use, **societal**
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Energy Consumption (Indicator ID: 7057)

Measure
Energy use in kilowatt hours per capita.

Purpose
To assess the amount of energy consumed in the Great Lakes basin per capita, and to infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

Ecosystem Objective
Sustainable development is a generally accepted goal in the Great Lakes basin. This indicator supports Annex 15 of the GLWQA.

Endpoint
Resource conservation minimizing the unnecessary use of resources is an endpoint for ecosystem integrity and sustainable development.

Features
The indicator is useful on a state/province/country basin basis. The trend for energy use has been increasing over time, which this indicator will depict as it tracks annual energy use.

Illustration
The indicator will be shown as a measure of kilowatt hours electrical energy used per capita.

Limitations
While the data are readily abundant for electrical energy, it will be more difficult to assess other energy sources such as hydrocarbon used in transportation, wood burned in fireplaces, natural gas and furnace fuels. This will require considerable effort.

Interpretation
Energy is a key aspect of ecosystem sustainability. The second law of thermodynamics is a starting point to understanding the way in which energy plays a key role in long term sustainability. Reducing the use of energy of all kinds will reduce 'entropy' and ensure a more sustainable future. Although electrical energy is a good proxy for total energy use, a complete accounting of all energy used is desirable. Although all forms of energy should be considered for conservation, electrical energy is used as a proxy.

Comments
Canada and the United States are among the highest energy consuming nations on Earth.

The indicator provides a quantitative measure of the rate at which non-renewable natural resources are being used up and that renewables are being consumed.

Electrical energy generation is among the largest source of smog related pollutants. In addition, it also generates a major share of all greenhouse gases that are responsible for global climate change.

Unfinished Business
- Need to develop a more quantitative endpoint.
- Need to determine how this indicator will be presented - as a graph, on a map, etc?
- Need to develop a baseline or reference value to be used in assessing whether energy use is increasing or decreasing over time.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, humans
Related Issue(s): climate change, stewardship
SOLEC Grouping(s): land use, **societal**
GLWQA Annex(es): 15: Airborne toxic substances
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Solid Waste Generation (Indicator ID: 7060)

Measure
Amount of solid waste generated per capita (tons and cubic metres).

Purpose
To assess the amount of solid waste generated per capita in the Great Lakes basin, and to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

Ecosystem Objective
Sustainable development is a generally accepted goal for Great Lakes basin society. This indicator supports Annex 12 of the GLWQA.

Endpoint
The reduction of waste to levels achieved in some European and Asian nations.

Features
Solid waste is generated and deposited on land or is incinerated and the residue remains on the land while other contaminants are redistributed by air and water sources. Solid waste represents a significant portion of all human land activities that generate waste and pollution and is stressful to the ecosystem. The indicator represents waste that goes to hazardous and non-hazardous landfills, as well as incinerators. Annual rates of waste generation will be presented by this indicator and bi-annual reporting will be useful.

Illustration
The indicator will be displayed as tons (tonnes) and cubic metres per capita in jurisdictions and for the basin over time. The indicator will be for all solid wastes over time.

Limitations
Although data are available for all jurisdictions, this indicator will require data coordination and integration. Variability in waste stream composition will result in the need for different types of measurement, such as weight versus volume, and may produce conflicting indications of progress. Regardless of the manner of disposal, the measure should consider the total volume of disposed solid waste. Therefore, important land contamination issues, such as acres of land fill space, will not be dealt with in this indicator.

Interpretation
Solid waste provides a measure of the inefficiency of human land based activities and the degree to which resources are wasted by the creation of waste. Reducing volumes of solid waste are indicative of a more efficient industrial ecology and a more conserving society. Reduced waste volumes are also indicative of a reduction in contamination of land through landfilling and incineration and thus reduced stress on the ecosystem.

Comments
Canada and the U.S. are among the highest waste producers on Earth. Reuse and recycling are opportunities to reduce solid waste levels.

Solid waste stored in sanitary landfills is a major source of methane, a very important greenhouse gas responsible for global climate change. Incineration of mixed solid waste has been shown to be a significant source of mercury and dioxins.

Unfinished Business
- Need to determine a specific endpoint.
- Need to determine a baseline value to use for assessing positive or negative trends in the amount of solid waste generated.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, land, humans
Related Issue(s): contaminants & pathogens, climate change, stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es): 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Financial Resources Allocated to Great Lakes Programs

(Indicator ID: 8140)

Measure
The total amount of dollars spent on an annual basis by federal and state/provincial agencies and non-governmental organizations in each of four areas: Great Lakes research, monitoring, restoration, and protection (including within nearshore lands).

Purpose
To assess the amount of dollars spent annually on Great Lakes programs, and to infer the responsiveness of Great Lakes programs through annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

Ecosystem Objective
Programs should be responsive to the degradation of shoreline communities and species.

Endpoint
Fully funded research, monitoring, restoration, and protection programs for Great Lakes ecosystems.

Features
This indicator will track the amount of dollars spent annually on Great Lakes research, monitoring, restoration, and protection programs. It will assess the number of projects, funding levels, and number of researchers across various factors, including type of funding source (e.g., government, non-government, private sector); levels of governments (e.g., local, State, Federal); basin wide; lakewide; regions of special interest; and types of research and locations. Data collection for this indicator will require a survey of major funding agencies, organizations and universities to identify key individuals and types of research or projects. The trends illustrated by this indicator can be used to determine which areas/issues require additional support, and where there are opportunities to shift funding.

Illustration
Summary tables or graphs will be displayed for the entire basin and for each lake showing trends in the number of resources allocated for research, monitoring, restoration, and projection programs and projects.

Limitations
Because it is often difficult to determine the spatial focus of various research projects (e.g., nearshore versus coastal wetlands), this indicator may double-count, or overlook, resources allocated to projects. A lack of historical data will make the assessment of funding trends over time difficult. To date, there has been no effort to collect this data. To initiate such an effort, and examine trends every 3 to 5 years, would require a substantial commitment. Obstacles to information collection may include freedom of information issues and difficulties in assessing private sector research efforts.

Interpretation
This indicator could be used to compare investments in Biodiversity Investment Areas to overall program spending, or to other program areas such as restoration. A baseline will be established to determine what resources a program requires to be considered "fully funded." This information will serve as a baseline to determine if the endpoint for this indicator has been achieved.

Comments
Received comments that this measure may be too dependent on political climate and not directly related to the benefits of the programs themselves. It is not clear how spending money is a meaningful or particularly sensitive societal response. This indicator should measure successful action. While it is agreed that this measure is not perfect, it can provide an initial estimate of the amount of attention given to various components of the Great Lakes ecosystem, such as nearshore terrestrial areas, over the long term. This indicator could be expanded to include factors such as the number of programs, policies, plans prepared, etc. as other indicators of agency interest.

This indicator may benefit from a ranking system that allows the return on investment to be assessed over time.
A change in funding levels may not be a reflection of the amount of attention the Great Lakes receive, but rather a reflection of budget issues.

Unfinished Business
- Need to determine a quantitative reference value, such as a particular dollar amount based on programs needs assessed on an annual basis.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Climate Change: Number of Extreme Storms (Indicator ID: 4519)

Measure
For land areas adjacent to the Great Lakes, total number of "extreme storms", per year during ice-free and ice-break-up periods on the Great Lakes.

Purpose
To assess the number of "extreme storms" each year, and to infer the potential impact on ecological components of the Great Lakes of increased numbers of severe storms due to climate change.

Ecosystem Objective
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in atmospheric temperature will potentially affect the number of extreme storms in the Great Lakes region which will, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor and minimize biological disruption.

Endpoint
An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average number of extreme storms on the Great Lakes prior to a particular date.

Features
Extreme storm events are a natural stressor than can occur anywhere in the basin and can potentially alter coastal wetlands and indicators of wetland health. There is natural variability in occurrences of extreme storm events, but the interpretation method tries to account for this, so the final score should have lower variability over time. Criteria to define an "extreme storm" (e.g., any storm below a central atmospheric pressure threshold or above a wind speed threshold) must be set.

This indicator may show similar trends to other indicators of climate change (ie. 4857, First Emergence of Water Lily Blossoms in Coastal Wetlands and 4858, Ice Duration on the Great Lakes). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

Illustration
A graph with the total number of extreme storm events (not ice-bound) on the y axis and years on the x axis, beginning with the cut-off date for historical data. The graph will also indicate the historical median and extremes.

Limitations
This indicator assumes that: 1) of all storms, "extreme storms" alter coastal wetlands the most (due to the combined effects of wind and waves; 2) storms throughout the basin represent storm effects on wetlands throughout the basin; and 3) historical data is available. It may take some time to collect data and to define historical reference levels.

Interpretation
To interpret this indicator, data for "extreme storms" need to be gathered each year. From the recorded data of "extreme storms", the pre-1980 median, maximum and minimum will be determined. The historic range will be divided into 3 equally occurring ranges: below average, average, and above average (i.e., the number of extreme storms/year exceeded 0-33.3%, 33.3% to 66.7%, 66.7% to 100% of the years of record before 1980). The indicator will score high if the annual numbers of extreme storms for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual Extreme storm numbers of the previous 10 years lie beyond the maximum or minimum extremes or they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Water levels, fetch and direction of storms may affect how storms influence individual wetlands.

Comments
The concept of storm damage is very understandable to public.

An endpoint could be reached when the previous 10 years' values of numbers of extreme storms are evenly distributed within the pre-1980 historic range of number of extreme storms.

A technical report written by P.J. Lewis will provide a good starting point for historical data and assessment. The report was published by the Canadian Climate Centre, Technical Report #87-13, Severe Storms Over the Great Lakes: A Catalogue and Summary. 1957-1985. This report gives a fair amount of detail about each storm that had a least two reports of storm force winds (>48 knots) or greater.

Unfinished Business

- Need a definition of "extreme storms" - will it be based on wind speed, amount of precipitation, central atmospheric pressure of the storm, or the pressure gradient? Or some combination of two or more criteria.

Relevancies

Indicator Type: pressure
Environmental Compartment(s): air
Related Issue(s): climate change
SOLEC Grouping(s): coastal wetlands, nearshore terrestrial, **unbounded**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

October 20, 1999

Climate Change: First Emergence of Water Lily Blossoms in Coastal Wetlands (Indicator ID: 4857)

Measure
The number of days after January 1 of first sighting of white on a water lily blossom, averaged over a representative set of coastal wetlands.

Purpose
To assess the change over time in first emergence dates of water lilies in coastal wetlands as a sentinel of climate change affecting the Great Lakes.

Ecosystem Objective
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in temperature potentially affects most biota. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption.

Endpoint
An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average historical emergence date of water lilies, and to determine the earliest and latest recorded dates of first emergence. If no historical data are available, the endpoint will need to be established from data gathered from monitoring this indicator.

Features
To monitor this indicator, a set of representative coastal wetland sites will be selected based on: 1) climate zones, 2) local observers and 3) associated historical data. The data will be collected annually. The data will have some variability due to natural climate variability and this will have to be considered when interpreting the data. Provided there are enough sites that meet the required criteria, collection and analysis of this indicator should be feasible.

This indicator may show similar trends to Ice Duration on the Great Lakes. It will be indirectly linked to indicators affected by climate change.

Illustration
A graph will be displayed showing, annually, the number of days after January 1 (average of the sites) of the first sighting of white on a water lily blossom. The average historical emergence data, and the earliest and latest recorded dates, will be marked for reference and comparison.

Limitations
A possible limitation may be locating sites that meet the needed criteria including on-site wetland observers and accessible water lilies. Monitoring would require frequent site visits for a period of time each year.

Interpretation
To interpret this indicator, data for the white water lily or for a highly correlated reference crop need to be gathered. From the recorded date of first emergence, the historical earliest and latest dates will be determined. The historic range will be divided into 3 equally occurring date ranges: early, average, and late. Scores will be designed to be high if the annual averages for the previous 10 years are within high and low historical extremes AND they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if annual averages lie beyond the high or low extremes OR they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Comments
This indicator allows local people to become involved and aware of SOLEC. This indicator may have to be rethought if water lily data do not correlate well with historical data for a reference crop.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): climate change
SOLEC Grouping(s): coastal wetlands, **unbounded**

GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Climate Change: Ice Duration on the Great Lakes (Indicator ID: 4858)

Measure

Maximum percentage of Great Lakes area covered by ice each year.

Purpose

To assess the temperature and accompanying physical changes to each lake over time, and to infer potential impact of climate change on wetlands.

Ecosystem Objective

GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in water temperature (potentially due to global warming) will affect ice extent on the Lakes and, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption.

Endpoint

An endpoint will need to be established, based on a literature search of historical data to determine the average number of days per year that ice historically (prior to 1980) formed on each lake.

Features

Ice cover reflects temperature, wind, and heat stored in a lake, therefore, this is a good indicator of climate effects. This data is already collected annually for each lake by NOAA using satellite imagery. There is a natural variability in MAXIMUM ice extent accounted for in the interpretation.

This indicator may show similar trends to other indicators of climate change (ie. 4519, Number of Extreme Storms, 4857, First Emergence of Water Lily Blossoms in Coastal Wetlands, and 4861, Water Level Fluctuations). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

Illustration

A graph displaying the maximum percentage of ice cover on the y axis and years on the x axis. The historical median and extremes will be indicated.

Limitations

The data that have already been collected by NOAA are specific to each lake rather than coastal wetlands.

Interpretation

Even though it is unclear if storms alter ice extent, storms can break up ice and alter their formation, therefore, information regarding storms and their severity is needed to properly interpret this indicator.

To interpret this indicator, data for maximum percentage ice cover need to be gathered each year. From the period of record for maximum percentage of ice cover, the pre-1980 high and low extremes will be determined. The historic range will be divided into 3 equally occurring ranges of maximum per cent ice cover: below average, average, and above average (i.e., maximum per cent ice cover exceeded 0 to 33.3%, 33.3% to 66.7%, 66.7% to 100% of the pre-1980 years of record). The indicator will score high if the annual maximum percentage values for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual maximum percentage cover value lies beyond the high or low extremes or if the annual values are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Comments

This is a very understandable feature. Lake ice indicates coastal wetland ice and itself affects wetlands (e.g., winter storm severity).

The endpoint is reached when the previous 10 years' values of maximum per cent ice cover are distributed evenly within the pre-1980 historic range of maximum per cent ice cover.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): climate change
SOLEC Grouping(s): open waters, nearshore waters, coastal wetlands, **unbounded**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised

Feb. 24, 2000

Breeding Bird Diversity and Abundance (Indicator ID: 8150)

Measure

Diversity and abundance of breeding bird populations and communities in selected habitat types, and an avian index of biotic integrity.

Purpose

To assess the status of breeding bird populations and communities, and to infer the health of breeding bird habitat in the Great Lakes basin.

Ecosystem Objective

This indicator supports Annex 2 of the GLWQA.

Endpoint

For this indicator, the desired outcome would vary by species and habitat type. A target of no decline in area-sensitive bird species (forest/grasslands/savannah) could be established for a select group of species within each habitat type being sampled. A target of increasing populations of contaminant-sensitive bird species in coastal breeding territories could also be established and monitoring protocols designed to assess attainment. A target of 90% of the monitoring stations achieving species presence equal to 90% of the expected number based on habitat and range could be a third type of desired outcome.

Features

The Great Lakes basin supports a rich diversity of breeding bird species. This region is one of the most important regions on the North American continent for abundance and diversity of breeding birds. Long-term, comprehensive monitoring of the status and trends of bird populations and communities can allow resource managers to determine the health of bird communities and habitat conditions. Because breeding birds are strongly linked to habitat conditions, this indicator has potential to have cross applications to other wildlife taxa and other indicators.

An "index of biotic integrity" has been used successfully in other areas and while its application to bird communities is in the experimental stages, it should be considered. For this approach to be successful across the Great Lakes basin, reference areas with healthy bird communities would be identified and compared with other, potentially less healthy areas. Commonly-used indices of diversity (e.g., species richness, Shannon-Weiner, Simpson's) could be used to describe the health of the bird community in selected habitat types and could be tracked over time.

Illustration

Data from this indicator could be presented in a variety of ways. Population status and trends for bird species of interest could be illustrated by simple line graphs representing selected geographic areas or the whole basin. Comparison graphs showing area sensitive forest bird species and species pre-adapted to highly modified landscapes could be used to show effects of land use changes across the basin. Indices of biotic integrity for areas surveyed would be presented in bar graph form and compared to other areas for which the index has been calculated. Broader scaled biodiversity patterns across the Great Lakes basin could be presented in map form that identify key habitat areas (biodiversity investment areas, protected areas, biodiversity hot spots). These maps could also be used to illustrate changes in bird population patterns over time.

Limitations

Confidence in using these data to express the health of a large-scale, diverse ecosystem, would depend on having site specific data that adequately represented the range of habitat conditions in the region. For example, relying only on bird monitoring activity in National Parks, where disturbance and fragmentation of habitat is likely low, could result in overly optimistic pictures of population trends or ecosystem health. Conversely, reliance on data from easily accessible areas such as road-side counts, could lead to indices threat suggest conditions are worse than they really are. Data gathering for this indicator is personnel intensive during the short, early-summer breeding season. To adequately survey the Great Lakes basin will require large numbers of trained staff and substantial travel expenses.

Interpretation

Changes in abundance, density, and productivity are caused by many factors both on and off the breeding territories. Care must be used in determining the causes of these changes, especially for birds that spend much of each year on migration or in distant wintering habitats. Utilizing information from ongoing research and management on migration routes and wintering areas will be essential for interpreting these data.

Comments

Populations and communities of birds have been used to indicate a wide variety of ecological stressors and processes. Birds are abundant in many habitat types. They make up about 70% of the terrestrial vertebrate species in Great Lakes forests for example. Understanding population dynamics and habitat associations of breeding birds will aid in understanding major elements of ecosystem health.

By following a consistent protocol of 10 minute point counts by highly trained professional bird surveyors, stratifying points by habitat, prioritizing habitats to be surveyed, and conducting surveys only on rain-free, calm days, compatible data can be collected by many researchers and agency staff. Substantial agreement and consistency has already been achieved on survey methodology by researchers across the Great Lakes basin.

Habitat analysis and landscape assessment of the Great Lakes basin (see habitat cover indicators) would allow a monitoring protocol to be developed that would identify priority habitat types. It would also allow a stratified, random sampling design, based on relative area of habitat types to be developed. This would provide a more valid, robust and geographically integrated monitoring program than what now exists. Monitoring efforts ongoing in several National Forest (Superior, Chequamegon) and National Parks (Apostle Islands, Isle Royale) and the USFWS Breeding Bird Survey can be used to take model elements for developing this indicator. The Ontario Forest Bird Monitoring Program and Marsh Monitoring Program also provide site-specific data which could be integrated into this indicator. A Great Lakes basin-wide monitoring protocol for gathering habitat-specific information on the status and trends of bird populations and communities, coordinated with systematic, landscape-scale vegetation data will allow basin-wide biodiversity mapping based on bird populations. For most habitat types and bird taxa, monitoring is most efficient when survey data on all singing birds are collected. Multiple indices of ecosystem health can then be calculated based on data gathered.

This indicator allows interpretation at multiple scales. Population trends of an individual species within a limited geographic area provides useful information to land managers and may suggest specific management activities that should be undertaken. Comparisons of indices of biotic integrity among sites would provide a way to evaluate the variety of management strategies employed in similar environmental settings. Analysis of broad patterns, using biodiversity maps provide opportunities to identify landscape level activities that influence ecosystem health.

Expansion of ongoing monitoring and efforts to standardize data gathering and quality control would be one way to approach the development of this indicator with the funds that might realistically be expected.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): habitat
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Threatened Species (Indicator ID: 8161)

Measure

Number, extent, and viability of species ranked as G1-G3 or S1-S3 in the Biological Conservation Database. A global or "G" rank is assigned on the basis of relative endangerment based primarily on the number of occurrences of the element globally. A rank of G1 means critically imperiled globally due to extreme rarity or due to factor(s) making it very vulnerable to extinction. A rank of G2 means imperiled globally due to rarity or due to some factor(s) making it very vulnerable to extinction throughout its range. A rank of G3 means either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range or due to other factors making it vulnerable to extinction throughout its range. A state or "S" rank focuses on the status of a species or ecosystem within the boundaries of a state. A rank of S1 means critically endangered with less than five known occurrences. A rank of S2 means six to twenty occurrences which are to some extent threatened. A rank of S3 means very rare or local throughout its range.

Purpose

To assess the number, extent and viability of threatened species, which are key components of biodiversity in the Great Lakes basin, and to infer the integrity of ecological processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

Ecosystem Objective

Healthy populations of all vegetation and wildlife, including the rarest of species. This indicator supports Annexes 2 and 17 of the GLWQA.

Endpoint

Viable populations of G1-G3 or S1-S3 species that are stable and persistent over the long term, even though local populations may fluctuate significantly in time and space.

Features

The rarest species of an ecosystem are indicators of the health of and stresses on the ecosystem. This indicator would emphasize vascular plants for ease of sampling, and would include wildlife to the extent possible. Optimum sampling methods would need to be determined. Representative areas of large size (e.g. 10 km x 10 km square with appropriate habitat) would be selected with ecological subdivisions supporting the species, and sampled at 2-5 year intervals at coarse and fine scales to document locations, aerial extent, and numbers target species. Sampling area size and timeline for trend analysis might vary by species, depending on the habitat and life history. Comparison of successive sampling results would be used to identify short and long term trends. It would be important to select sampling areas that are ecologically relatively intact, as well as some with varying degrees of observable human impact.

Illustration

Graphs of population numbers for each target species over time per sampling site, ecoregion, and basin-wide.

Limitations

It would be costly to annually monitor all populations of all species. A subset could be sampled annually, to determine trends that might be applicable to the entire set. Certain species are more sensitive to change than others.

Interpretation

Natural environments are dynamic by nature, therefore, local decreases or even extirpations of a threatened species may be normal. On the other hand, local extirpations can also be linked to human alterations of habitats through activities such as development. Measures will need to be interpreted with contextual information on anthropogenic disturbances, and need to be taken over sufficient space and time to generate a "big picture" of metapopulations in contiguous or semi-contiguous habitats. Overall stability or increases in viable populations indicates integrity of key supporting processes to which the species are adapted. Overall decreases in population numbers and/or extent can signal deterioration of key processes that maintain suitable habitat.

Comments

Experts from the states/provinces should collectively decide which species would be the best indicators. Using the ranking system from the Biological Conservation Database provides a more uniform assessment of status across jurisdictions, and provides access to an existing digital database.

Unfinished Business

- Need to provide quantitative values for "viable populations."

Relevancies

Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Acid Rain **(Indicator ID: 9000)**

Measure
1) Levels of pH in precipitation in the Great Lakes Basin, and 2) the area within the Great Lakes basin in exceedance of critical loadings of sulphate to aquatic systems, measured as wet sulphate residual deposition over critical load (kg/ha/yr).

Purpose
To assess the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and to infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.

Ecosystem Objective
The Canada/U.S. Accord on Air Quality pledges the two nations to reduce the emissions of acidifying compounds to the point where deposition containing these compounds does not adversely impact aquatic and terrestrial biotic systems. This indicator supports Annexes 1 and 15 of the GLWQA.

Endpoint
Levels of sulphate in wet deposition are not to exceed critical loads, defined by ecozone to be from 8 - 20 kg/ha/yr.

Features
Measurements of sulphate deposition and pH are made by the US NDDN and Canadian CAPMoN networks along with provincial and state partners. These data are stored in databases on both sides of the border.

Illustration
Data are routinely extracted from databases into annual maps of sulphate and pH deposition. These maps will be used to depict this indicator.

Limitations

Interpretation
This measure is not sufficient to fully understand the deposition problem and trends in pH concentration throughout the basin is another related indicator. Areas exceeding the sulphate critical load continue to be ecologically stressed due to high levels of acidity.

Comments
Current projections how that this may not occur until after 2010. The two specific measures tracked both provide indication of progress towards the goal of reducing acidifying substances.

Further progress in reduction of acidifying substances are required.

Unfinished Business
- Need to determine what the target pH level is.
- Need to add more information on how often measurements of sulphate and pH are made, and the spatial trends (i.e., location of monitoring sites within the Great Lakes basin) described by this indicator.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water, land
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 15: Airborne toxic substances
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Exotic Species (Indicator Code: 9002)

Measure

Purpose

This indicator will assess the presence, abundance and distribution of invasive exotic species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. *This indicator is under development. It has been added to the SOLEC list in response to suggestions from multiple reviewers of the Version 3 list of SOLEC indicators.*

Ecosystem Objective

Endpoint

Features

Illustration

Limitations

Interpretation

Comments

Unfinished Business

Relevancies

Last Revised

Feb. 25, 2000

Appendix 2 — Complete Listing of Indicators (entered into the database)

The attached table contains a listing of over 800 indicators that have been entered into the database. The table includes:

- the indicator name,
- the indicator number or code,
- what the indicator measures, and
- whether the indicator has been proposed for the SOLEC Indicator List (C.R. means Concept Retained in another indicator). *Note - those indicators that are included in the SOLEC Indicator List are shown shaded for ease of identification.*

1	Lake herring	Rehabilitate to historical level of production	No
2	Lake trout	Restore self-sustaining stocks to historical abundance	C.R.(93)
3	Non-depleted native fishes	Maintain stable, self-sustaining status	No
4	Depleted native fishes	Restore stable self-sustaining stocks	No
5	Sea lamprey	Reduce population by 50% by 2000; 90% by 2010	No
6	Fish Habitat	1) Quality and area of aquatic habitat (e.g., shore, spawning shoals, tributaries, wetlands, etc.) and 2) population of sentinel fish species. For example, the measures for tributary quality could include the number of dams, number of miles of river channel that is impounded, number of miles of (formerly) high-gradient stream channel that is impounded, and the number of miles between the river mouth and the first dam. The number and location of fish passage facilities (up- and downstream) that could be used successfully by species or communities of concern (for example, lake sturgeon, or other anadromous fishes listed in FCGO) could also serve as measures.	Yes
7	Fish consumption advisories	Reduce level in fish below FCA action levels	No
8	Salmon and Trout	1) Productivity, yield, or harvest of Pacific salmon, rainbow trout and brown trout using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) populations of these stocked and naturally produced fish.	Yes
9	Walleye and *Hexagenia*	Abundance, biomass, or annual production of walleye and burrowing mayfly (*Hexagenia* spp.) populations in historical, warm-coolwater, mesotrophic habitats of the Great Lakes. Presence or absence of a *Hexagenia* mating flight (emergence) in late June- July in areas of historical abundance.	Yes
10	Yellow perch	Maintain as top omnivore; 0.5Mkg/y	No
11	Northern pike	Maintain as prominent predator	No
12	Muskellunge	Manage to support trophy fishery	No
13	Lake Whitefishes	Quantify using either numbers or biomass.	No
14	Lake whitefish and lake herring	Maintain self-sustaining stocks yielding 3.8Mkg/y	No
15	Bass and sunfish	Maintain at recreationally attractive levels	No
16	Lake sturgeon	Rehabilitate populations; delist as T or E spp.	No
17	Preyfish Populations	Abundance and diversity, as well as age and size distribution, of preyfish species (i.e., deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives) in each lake.	Yes
18	Sea Lamprey	Number of spawning run adult sea lampreys; wounding rates on large salmonids.	Yes
19	Native species diversity	Total number of different species in a collection (see features). Comparison of historical with present conditions.	No
20	Genetic diversity	Heterozygosity (allozyme, allelic);nuclear or mitochondrial DNA polymorphisms; population pairwise genetic distance; nucleon diversity/gene diversity; genetic variability; genetic uniqueness.	No
21	Habitat	No net loss; rehabilitate degraded habitats	No
22	Habitat	Reduce or eliminate contaminants	No
23	Salmon and trout	Establish diverse community yielding 6-15Mlbs/y	No
24	Planktivores (preyfish)	Match to primary production and predator demand	No
25	Inshore fish	Maintain self-sustaining stocks; yield >2-4Mlbs/y	No

26	Benthivore (fish)	Maintain self-sustaining stocks	No
27	Benthivore (lake whitefish)	Maintain self-sustaining stocks; yield 4-6M lbs/y	No
28	Sea lamprey	Reduce to achieve other fish community objective	No
29	Other species (fish)	Protect diverse native fish community	No
30	Habitat	No net loss; restore riverine spawning habitat	No
31	habitat	Reduce or eliminate contaminants	No
32	Lake trout	Restore self-sustaining populations; 0.5-1 M adult	No
33	Warmwater fish	Maintain current complex; yield 1 kg/ha/y	No
34	Preyfish	Maintain major species; mean biomass 110 kg/ha/y	C.R.(17)
35	Salmon, trout, and whitefishes	Maintain diverse complex; yield 2.5 kg/ha/y	No
36	Sea lamprey	Limit lake trout mortality to<90,000 fish/y	No
37	Lake trout	Health indicator for coldwater fish community	No
38	Walleye	Health for mesotrophic ecosystem; yield .3 kg/ha/y	No
39	Hexagenia (burrowing mayfly)	Health indicator for mesotrophic ecosystem	No
40	Exotic species	Effects of	No
41	Native species and habitats	Status of	No
42	Persistent toxics	Levels in water and sediment	No
43	Persistent toxics	Levels in fish and wildlife	No
44	Nutrient loading	DO levels in bottom waters	No
45	Nutrient loading	Water clarity and algal blooms	No
47	Nutrient loading	Maintain mesotrophic conditions (10-20 ug P/L)	No
48	Nutrient loading	Manage loadings to yield 50-60 M lbs good fish/y	C.R.(111)
49	Habitat	Manage nearshore habitat for quality fisheries	No
50	Riverine habitat	Protect spawning habitat of anadromous fish	No
51	Western basin ecosystem	Manage for warm and coolwater fishes	No
52	Central basin ecosystem	Manage for warm, cool, and coldwater fishes	No
53	Eastern basin ecosystem	Emphasize management for coldwater fishes	No
54	Contaminants	Reduce levels to no effect on fish production	C.R.(112)
55	Habitat	Adequate habitat to support fish community goals	No
56	Genetic diversity	Conserve locally adapted strains	No
57	Rare, Threatened & Endangered species	Manage to preserve and protect	No
58	Preyfish	Manage as prey, baitfish, and human food (smelt)	No
59	Food web	Manage to meet fish community objectives	No
60	Diaporeia and Hexagenia	Manage as prey and indicators of habitat quality	No
61	Biomass/production size spectrum	Ecosystem structure	No
62	Yield of piscivores	Commercial and sport catch	No
63	Piscivore/prey biomass	Ecosystem health	No
64	Fraction of yield as native fish	Ratio of native to exotic species of fish.	C.R.(8)
65	Zooplankton size distribution	Ecosystem structure; predation, and productivity	No
66	Total P levels <= 10 mg/L	Baseline productivity	No
67	Small native bivalve presence	Ecosystem health	No
68	Native Unionid Mussels	Distribution and abundance, reported as number of individuals per unit of sampling effort; soft tissue weight; and reproductive output of the Native Unionid mussel.	Yes
69	Submersed aquatic vegetation	Condition of physical habitat; nutrient loading	No
70	Municipal discharges: BOD, TSS, Pf	Water quality	No
71	Petroleum industry liquid discharges	Water quality	No
72	Fish Entrainment	1) Water withdrawal rates in m^3/sec (gal/min) at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes; and 2) calculated total annual mortalities (losses) of sentinel species at each plant in each lake.	C.R.(6)
73	Fishability	Contaminant levels in fish; fish advisories	No
74	Biological community integrity and diversity	Multiple; biota and habitat	No
75	Virtual elimination persistent toxics	Multiple; mixed	C.R.(112)
76	Phosphorus	Multiple; mixed	C.R.(111)
77	Physical environment integrity	Multiple; mixed	No
78	Loss of native species	Number of species lost	No
79	Ecosystem imbalance	Lake trout dichotomous key	No
80	Reproductive impairment	EMS; female parent contaminant body burden	No
81	Nutrient stress	P level, DO level; Chlorophyll a	C.R.(111)

Ind. code	[illegible]	Measure	[illegible]
82	Contaminant stresses	loadings, residues, body burdens	No
83	Lake trout	lake trout dichotomous key	No
84	Mesotrophic biological surrogates	Walleye and Hexagenia	No
85	Fish habitat--in 43 AOCs	Habitat supports fish community objectives	No
86	Fish community	Site specific; 43 sites	No
87	Habitat	Areas of aquatic vegetation and loose rock substrate	No
88	White sucker	Basin-wide toxics	No
89	Lake trout	Oligotrophic habitats	No
90	Walleye, Hexagenia	Basin-wide mesotrophic habitats	No
91	Brown bullhead, Hexagenia, benthic community	Toxics in AOCs	No
92	Walleye and Hexagenia	Walleye, 0.3kg/ha/y; Hexagenia, 200/m2/y/3y	No
93	Lake Trout and Scud (*Diporeia hoyi*)	Abundance, yield, or biomass, and self-sustainability of lake trout and scud (*D. hoyi*) in coldwater, oligotrophic habitats of the Great Lakes.	Yes
94	Fish community structure and function	Annual harvest of trout and salmon (M lbs)	No
95	Fish community structure and function	Annual harvest of planktivores (M lbs)	No
96	Fish community structure and function	Annual harvest of inshore fishes (M lbs)	No
97	Fish community structure and function	Annual harvest of benthivore fishes (M lbs)	No
98	Fish community structure and function	Annual harvest of other native fishes (M lbs)	No
99	Reproduction and self-sustainability	Lake trout	No
100	Fish habitat and spawning grounds	lake trout spawning habitat; coastal wetland sp. H	No
101	Deformities, Eroded Fins, Lesions and Tumours (DELT) in Nearshore Fish	Frequency of tumors and other related anomalies in nearshore fish.	Yes
102	Tainting of fish flavor	Annual number of complaints for sport fish	No
103	Exotics	lamprey wounding rates; presence of other species	No
104	Benthos Diversity and Abundance	Species diversity and abundance in the aquatic oligochaete community.	Yes
105	Tributaries	Macroinvertebrate community; IBI, MBI, etc.	No
106	Dredging activities	Contaminant level in sediments	No
107	Contaminant levels to protect aquatic life	Concentration of toxics in water column	No
108	Eutrophication	Total P and ammonia in water	No
109	Phytoplankton Populations	Phytoplankton biomass (species and size composition) and size-fractionated primary productivity (Carbon-14 uptake or photosynthesis) as indicator of microbial food-web structure and function.	Under Consideration
110	Zero discharge and emission of 9 toxic contaminants		C.R.(112)
111	Phosphorus Concentrations	Total phosphorus levels (ug/L).	Yes
112	Trends in Contaminant Concentrations & Loadings of Priority Chemicals in Abiotic Media: Water, Air, Soil, and Sediments	This indicator will use the contaminant concentrations and computational methodology to compute the loadings, trends, and exchanges of priority toxic chemicals between air, water, and sediment. Fugacity based approaches of intermedia transport will also be included as part of the indicator.	C.R.(117, 118, 119, 120)
113	Contaminants in Recreational Fish	Concentration of PBT chemicals in the catch-weighted average, edible tissue of recreational fish.	Yes
114	Contaminants in Young-of-the-Year Spottail Shiners	Concentration of PBT chemicals in young-of-the-year spottail shiners.	Yes
115	Contaminants in Colonial Nesting Waterbirds	1) Annual concentrations of DDT complex, PCBs/PCDFs/PCDDs and other organic contaminants and Hg and other metals in Herring Gull eggs from 15 sites from throughout the Great Lakes (U.S. and Canada). 2) Periodic measurement of biological features of gulls and other colonial waterbirds known to be directly or indirectly impacted by contaminants and other stressors. These include (but are not limited to): clutch size, eggshell thickness, hatching and fledging success, size and trends in breeding population, various physiological biomarkers including vitamin A, immune and thyroid function, stress hormone levels, liver enzyme induction, PAH levels in bile and porphyrins and genetic and chromsomal abnormalities.	Yes
116	Zooplankton Populations	1) Community Composition; 2) Mean Individual Size; and 3) Biomass and Production.	Yes
117	Atmospheric Deposition of Toxic Chemicals	Annual average loadings of toxic chemicals from the atmosphere to the Great Lakes, based on measured atmospheric concentrations of the chemicals, as well as wet and dry deposition rates.	Under Consideration
118	Toxic Chemical Concentrations in Offshore Waters	The concentration of toxic chemicals in the offshore waters of the Great Lakes.	Under Consideration
119	Concentrations of Contaminants in Sediment Cores	The concentrations of toxic chemicals in sediment cores at selected sites within the Great Lakes at ten year intervals.	Under Consideration

[illegible]	Indicator Name	[illegible]	[illegible]
120	Contaminant Exchanges Between Media: Air to Water, and Water to Sediment	Estimates of air to water and water to sediment loadings of toxic chemicals using fugacity based approaches of intermedia transport.	Under Consideration
1000	Biomass/Production Size Spectrum		No
1001	Excess Nutrients	Total Phosphorus and Nitrogen Levels	No
1002	Zooplankton Size Distribution	Mean Zooplankton Length	No
1003	Production or Yield of Piscivores		No
1004	Piscivore/Prey Fish Biomass Ratio		No
1005	Fraction Yield as Native Fish	Naturally Producing Fish to Salmonine Populations	No
1006	Contaminant Body Burdens	DDT, PCB, dieldrin concentrations in lake trout	No
1007	Burrowing Mayfly Nymphs	Easily quantified using either numbers or biomass	No
1008	Trends in Abundance of Key Species	Index Target Abundances (e.g. lake trout, diporeia	No
1009	Lake Herring Stocks	Annual Yields	No
1010	Salmonine Stocks	Annual Yields of Salmon and Trout	No
1011	Planktivore (prey) Species Biomass		No
1012	Rarity of Species and Communities		No
1013	Non-Native/Exotic Species		No
1014	Species Richness	Total number of different species in a collection	No
1015	Human Population Size	Population Size from census data	No
1016	Tern Populations	Common and Caspian Terns	No
1017	Herring Gull		No
1018	Bald Eagle/Osprey Populations		No
1019	Double-Crested Cormorant		No
1020	Contaminant Concentrations in Water	PCB, DDE, dieldrin, HCB, BaP	No
1021	Induction of Mixed Function Oxidase Enzymes	P450 1A1	No
1022	Inhibition of Amino Levulinic Acid Dehydratase		No
1023	Hepatic Porphyria		No
1024	Hepatic Vitamin A (Retinol)		No
1025	Thyroid Related Abnormalities		No
1026	Tumor Incidence		No
1027	Fin Ray Asymmetry		No
1028	Congenital Malformations		No
1029	Disease Incidence		No
1030	Parasite Incidence		No
1031	Walleye Abundance		No
1032	Exceedance of Water Quality Guidelines	Bacterial Contamination	No
1033	Total discharge via leakages	kg of pollutants and metals	No
1034	Contaminants discharged by STP in kg/day		No
1035	Industrial effluent discharged per day		No
1036	Zinc Loadings	Total kg per year	No
1037	Iron Loadings		No
1038	Phenols Loadings	Total kg per year	No
1039	TSS Discharge	Total kg/day	No
1040	Cyanide Loadings	Total kg/day	No
1041	BOD Loadings	STP effluent concentrations (mg/L)	No
1042	TSP Concentrations	mg/L	No
1043	Fecal coliform concentration	MF count/100 ml	No
1044	Chlorine Concentrations	mg/L	No
1045	Concentration of cadmium	mg/L	No
1046	Concentration of chromium	mg/L	No
1047	Concentration of lead	mg/L	No
1048	Concentration of aluminum	mg/L	No
1049	Concentration of Mirex	ng/L	No
1050	Concentration of copper	mg/L	No
1051	Growth rate of individuals		No
1052	Carcinogenesis		No
1053	Teratogenesis and Congenital Defects		No

[illegible]	[illegible]	[illegible]	[illegible]
1054	Susceptibility to Disease		No
1055	Behavioural Effects		No
1056	Morphological Changes	Algal cells, etc.	No
1057	Feminization		No
1058	Natality and Mortality		No
1059	Population Age Structure		No
1060	Number of Breeding Pairs		No
1061	Geographical Range of Population		No
1062	Decomposition		No
1063	Phosphorus Loadings	Chorophyte - Cladophora	No
1064	Fugacity	Partial pressure/escaping tendency of chemical	No
1065	Water Transparency		No
1066	Ratio of Specialist to Generalist Organisms		No
1067	Tainting of Fish Flavour		No
1068	Ammonia	Degradation of Phytoplankton and Zooplankton	No
1070	TKN	Degradation of Phytoplankton and Zooplankton	No
1071	Total Phosphorus	Degradation of Phytoplankton and Zooplankton	No
1072	Total Dissolved Si	Degradation of Phytoplankton and Zooplankton	No
1073	Total Organic Carbon	Degradation of Phytoplankton and Zooplankton	No
1074	Total Suspended Solids	Degradation of Phytoplankton and Zooplankton	No
1075	Chlorides	Degradation of Phytoplankton and Zooplankton	No
1076	Dissolved Oxygen	Degradation of Phytoplankton and Zooplankton	No
1077	Temperatures	Degradation of Phytoplankton and Zooplankton	No
1078	Secchi Depth	Degradation of Phytoplankton and Zooplankton	No
3500	Reinvestment in Natural Capital		No
3501	Citizen Involvement in Decision Making		No
3502	Per Capita Membership in Community Organizations		No
3503	Energy Consumption		No
3504	Waste Stream Loadings		No
3505	Political Pressure - Protect/Remediate Environment		No
3506	Diversity of Cultures		No
3507	Basin-Wide Sense of Identity		No
3508	General Participation in Environmental Programs		No
3509	Capacities of Sustainable Landscape Partnerships	Number of partnerships; basin location and geographic coverage; budgets, FTE staff; identification of major projects and initiatives	Under Consideration
3510	Organizational Richness of Sustainable Landscape Partnerships	The diversity of the members participating in partnerships measured on two axes: Horizontal Integration -- the diversity of local partners; and Vertical Integration -- the direct participation of federal and state/provincial actors in local partnership initiatives.	Under Consideration
3511	Integration of Ecosystem Management Principles Across Landscapes	Simple reporting of the adoption of ecosystem management as a guiding principle in place-based resource management programs by states/provinces and regional agencies and governments and budget allocations in support of ecosystem management programs and projects.	Under Consideration
3512	Integration of Sustainability Principles Across Landscapes	Simple reporting of the adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments and budget allocations in support of sustainability initiatives and projects.	Under Consideration
3513	Citizen/Community Place-Based Stewardship Activities	An enumeration and description of programs and projects that engage citizens in the stewardship of their landscapes / ecosystems and/or foster the ethic of stewardship; total number of identified programs, total number of participants, basin location.	Under Consideration
4078	Drinking Water Quality	Chemical concentration in finished drinking water	C.R.(4175)
4079	Drinking Water Quality	Microbial contaminants in finished drinking water	C.R.(4175)
4081	*E. coli* and Fecal Coliform Levels in Nearshore Recreational Waters	1) Counts of *E. coli* and/or fecal coliforms (FC) in recreational waters measured as number of organisms per volume of water (e.g., FC/ml); and 2) frequency of beach closings at specific locations.	Yes
4082	Contaminants in Air	Concentration of chemicals and particulates in ambient air	C.R.(4176)
4083	Contaminants in Edible Fish Tissue	Concentration of PBT chemicals targeted by the GLWQA in edible fish tissue	Yes
4084	Chemical Contaminants in Human Tissue 1	Breast milk: Concentration of PBT chemicals	C.R.(4177)

[illegible]	[illegible]	[illegible]	[illegible]
4085	Chemical Contaminants in Human Tissue 2	Blood lead concentrations in children	No
4086	Chemical Contaminants in Human Tissue 3	Geographic comparisons of chemical contaminants in human tissue (blood, milk and hair)	C.R.(4177)
4087	Chemical Contaminants in Human Tissue 4	Umbilical cord blood: Concentration of PBT chemicals	C.R.(4177)
4088	Chemical Contaminant Intake From Air, Water, Soil and Food	Estimated total daily intake of PBT chemicals targeted by the GLWQA from air, water, soil, and food sources.	Yes
4089	Radionuclides 1	Concentration of Cs-137 and Sr-90 in cow's milk	C.R.(4178)
4090	Radionuclides 2	Concentration of H-3 (tritium) and C-14 in surface water, drinking water, and air	C.R.(4178)
4091	Air Quality and Cardiorespiratory Health 1	Relationship between respiratory admissions to hospitals and ozone and sulphate levels.	C.R.(4176)
4092	Air Quality and Cardiorespiratory Health 2	Cardiorespiratory hospital admissions and sulfate levels	C.R.(4176)
4093	Cancer Risk and Chlorination Byproducts in Drinking Water	Correlation of THM levels in drinking water with cancer incidence	C.R.(4175)
4094	Cancer Incidence Rates	Geographic distribution of cancer incidence in the Great Lakes region	C.R.(4179)
4095	Birth Defects Incidence Rates	Geographic distribution of birth defect rates in the Great Lakes region	C.R.(4179)
4096	Social Indicators	Public knowledge, attitudes, and behaviors regarding use of Great Lakes resources	No
4102	Contaminants in Fish	Aldrin/dieldrin in Indicator Species	No
4103	Contaminants in Fish	Benzo(a)pyrene in Indicator Species	No
4104	Contaminants in Fish	Chlordane in Indicator Species	No
4105	Contaminants in Fish	DDT and metabolites in Indicator Species	No
4106	Contaminants in Fish	Hexachlorobenzene in Indicator Species	No
4107	Contaminants in Fish	Alkyl-lead in Indicator Species	No
4108	Contaminants in Fish	Mercury and compounds in Indicator Species	C.R.(4083)
4109	Contaminants in Fish	Mirex in Indicator Species	C.R.(4083)
4110	Contaminants in Fish	Octachlorostyrene in Indicator Species	No
4111	Contaminants in Fish	PCBs in Indicator Species	C.R.(4083)
4112	Contaminants in Fish	Dioxins and Furans in Indicator Species	C.R.(4083)
4113	Contaminants in Fish	Toxaphene in Indicator Species	C.R.(4083)
4114	Contaminants in Drinking Water	Lead in raw and treated water	C.R.(4078)
4115	Contaminants in Drinking Water	Mercury in raw and treated water	C.R.(4078)
4116	Contaminants in Drinking Water	Benzene in raw and treated water	No
4117	Contaminants in Drinking Water	Chlordane in raw and treated water	No
4118	Contaminants in Drinking Water	Dibromochloropropane in raw and treated water	No
4119	Contaminants in Drinking Water	Ethylenedibromide in raw and treated water	No
4120	Contaminants in Drinking Water	Toxaphene in raw and treated water	No
4121	Contaminants in Drinking Water	Hexachlorobenzene in raw and treated water	No
4122	Contaminants in Drinking Water	Benzo(a)pyrene in raw and treated water	No
4123	Contaminants in Drinking Water	PCBs in raw and treated water	No
4124	Contaminants in Drinking Water	2,3,7,8-TCDD in raw and treated water	No
4125	Contaminants in Drinking Water	Coliform in raw and treated water	C.R.(4079)
4126	Contaminants in Drinking Water	Fecal coliform in raw and treated water	C.R.(4079)
4127	Contaminants in Air	Ozone concentrations in air	C.R.(4082)
4129	Contaminants in Air	Particulate matter concentrations in air	C.R.(4082)
4130	Contaminants in Air	Carbon monoxide concentrations in air	C.R.(4082)
4131	Contaminants in Air	Volatile Organic Compounds concentrations in air	C.R.(4082)
4132	Recreational Water Quality	Enterococci concentrations in water	C.R.(4081)
4133	Recreational Water Quality	E. coli concentrations in water	C.R.(4081)
4134	Recreational Water Quality	Fecal coliform concentrations in water	C.R.(4081)
4135	Contaminants in Drinking Water	Viruses in raw and treated water	C.R.(4079)
4136	Radionuclides	XX concentrations in YY	No
4142	Organochlorines in human breast milk 01	Concentrations in breast milk of DDT	C.R.(4084)
4143	Organochlorines in human breast milk 02	Concentrations in breast milk of dieldrin	C.R.(4084)
4144	Organochlorines in human breast milk 03	Concentrations in breast milk of heptachlor epoxid	C.R.(4084)
4145	Organochlorines in human breast milk 04	Concentrations in breast milk of oxychlordane	C.R.(4084)

[illegible]	Indicator name	Measure	[illegible]
4146	Organochlorines in human breast milk 05	Concentrations in breast milk of transnonachlor	C.R.(4084)
4147	Organochlorines in human breast milk 06	Concentrations in breast milk of B-HCCH	C.R.(4084)
4148	Organochlorines in human breast milk 07	Concentrations in breast milk of HCB	C.R.(4084)
4149	Organochlorines in human breast milk 08	Concentrations in breast milk of PCB	C.R.(4084)
4150	Organochlorines in human breast milk 09	Daily intake of DDT by breast-fed infants	C.R.(4084)
4151	Organochlorines in human breast milk 10	Daily intake of dieldrin by breast-fed infants	C.R.(4084)
4152	Organochlorines in human breast milk 11	Intake of heptachlor epoxide by breast-fed infants	C.R.(4084)
4153	Organochlorines in human breast milk 12	Daily intake of oxychlordane by breast-fed infants	C.R.(4084)
4154	Organochlorines in human breast milk 13	Intake of transnonachlor by breast-fed infants	C.R.(4084)
4155	Organochlorines in human breast milk 14	Daily intake of B-HCCH by breast-fed infants	C.R.(4084)
4156	Organochlorines in human breast milk 15	Daily intake of HCB by breast-fed infants	C.R.(4084)
4157	Organochlorines in human breast milk 16	Daily intake of PCB by breast-fed infants	C.R.(4084)
4158	Organochlorines in human breast milk 17	Organochlorine pesticide index for breast milk	C.R.(4084)
4160	Geographic distribution of cancer	Cancer incidence	C.R.(4094)
4161	Birth defects in Ontario, 1978-1988	Birth defects incidence	C.R.(4095)
4162	Cancer risk/chlorination disinfection by-products	THM levels in drinking water + cancer incidence	C.R.(4093)
4163	Air pollutants affecting hospital admission rates	Daily respiratory admissions vs sulphate levels	C.R.(4091)
4164	Air pollutants affecting hospital admission rates	Daily respiratory admissions vs ozone levels	C.R.(4091)
4165	Air pollutants affecting hospital admission rates	Cardiorespiratory hospitalization rates vs levels of sulphates	C.R.(4092)
4166	Exposure to aldrin and dieldrin	Estimated daily intake	C.R.(4088)
4167	Exposure to benzo(a)pyrene	Estimated daily intake	C.R.(4088)
4168	Exposure to chlordane	Estimated daily intake	C.R.(4088)
4169	Exposure to DDT	Estimated daily intake	C.R.(4088)
4170	Exposure to dioxins and furans	Estimated daily intake	C.R.(4088)
4171	Exposure to PCBs	Estimated daily intake	C.R.(4088)
4172	Exposure to hexachlorobenzene	Estimated daily intake	C.R.(4088)
4173	Exposure to mercury	Estimated daily intake	C.R.(4088)
4174	Exposure to mirex	Estimated daily intake	C.R.(4088)
4175	Drinking Water Quality	Concentrations of chemical substances such as metals (e.g., lead, mercury) and other inorganic compounds, pesticides, radionuclides, and drinking water disinfection by-products (e.g., trihalomethanes) as well as microbial parameters such as bacteria, viruses and parasites in raw, treated and distributed drinking water.	Yes
4176	Air Quality	Concentration of chemicals and particulate matter in ambient air.	Yes
4177	Chemical Contaminants in Human Tissue	Concentrations of PBT chemicals targeted by the GLWQA in human tissues such as blood, breast milk, hair, urine and adipose tissues.	Yes
4178	Radionuclides	Concentration of Cs-137 and Sr-90 in cow's milk, gross beta activity in air and precipitation, and airborne and waterborne radionuclide emissions from nuclear power plants in the Great Lakes basin.	Yes
4179	Geographic Patterns and Trends in Disease Incidence	Disease incidence rate (rate = x disease incidences/ y population) of diseases that have a demonstrated environmental link, such as cancers and birth defects, in the Great Lakes basin.	Yes
4501	Coastal Wetland Invertebrate Community Health	Relative abundance of sensitive taxa (e.g., mayflies, caddisflies), tolerant taxa (e.g., Chironomini as a proportion of total Chironomidae abundance, Isopoda), richness of specific taxa, and functional feeding groups (e.g., herbivores, detritivores, carnivores), working towards the development of an Index of Biotic Integrity (IBI).	Yes

[illegible]	[illegible]	[illegible]	[illegible]
4502	Coastal Wetland Fish Community Health	An Index of Biotic Integrity (IBI) will be developed based on measures of species richness and abundance, percent exotic species, percent phytophils and other appropriate parameters.	Yes
4503	Deformities, Eroded Fins, Lesions and Tumors (DELT) in Fish	Numbers and percent of DELT in coastal wetland fish.	Yes
4504	Amphibian Diversity and Abundance	Species composition and relative abundance of calling frogs and toads, based on evening surveys using protocol developed for the Marsh Monitoring Program (MMP) or modification of MMP protocol.	Yes
4505	Reptile Diversity and Abundance	Species composition and abundance of basking turtles and snakes, based on surveys using protocol similar to the Marsh Monitoring Program (MMP) protocols for amphibian and bird surveys.	No
4506	Contaminants in Snapping Turtle Eggs	Contaminant levels in snapping turtle eggs	Yes
4507	Wetland-Dependent Bird Diversity and Abundance	Species composition and relative abundance of wetland-dependent birds, based on evening surveys using protocol developed for Marsh Monitoring Program (MMP) or modification of the MMP protocol.	Yes
4508	Mink Populations	Estimate of numbers of mink	No
4509	Contaminants in Mink	Measure levels of contaminants in wild mink of Great Lakes coastal wetlands.	No
4510	Coastal Wetland Area by Type	Areal extent of coastal wetlands by type as a range (e.g., dry year/low water level area versus wet year/ high water level area).	Yes
4511	Gain in Restored Coastal Wetland Area by Type	Gain in restored wetland area by type.	Yes
4512	Chlorophyll a Levels	Chlorophyll a levels	No
4513	Presence, Abundance & Expansion of Invasive Plants	Presence, abundance, & expansion of invasive plants (both native and non-native), such as flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pondweed, cattail, Phalaris, and Phragmites.	Yes
4514	Agricultural land use: risk of declining soil quality	Areas at risk of declining soil quality (primarily erosion) are calculated/estimated from their inherent soil loss (under natural cover), topography/slope, the type of crop grown, and agricultural management practices (e.g. conservation tillage).	C.R.(7007)
4515	Reported Toxic Releases	Total tons of reported toxic releases to water.	C.R.(4854,4855,4856)
4516	Sediment Flowing Into Coastal Wetlands	Suspended Sediment Unit Area Yield (tonnes/km^2 of upstream watershed) for a representative set of existing monitoring sites just upstream of coastal wetlands.	Yes
4517	Inflow Flow Alteration	Ratio of total high extreme flows to total low extreme flows for all existing monitoring sites just upstream of coastal wetlands.	No
4518	Water Level Fluctuations	Using IGLD 85 water levels and gauging stations best representing lakes and coastal wetlands: 1) Weighted 5-year moving average level index =[0.5 L(t) + 0.25 L(t-1) + 0.125 L(t-2) + 0.0625 L(t-3) + 0.03125 L(t-4)]/ 0.96875, where L(t) is the average lake level in year t (Busch, 1990). 2) Lake-wide annual range in monthly averages. 3) Lake-wide seasonal peak (days after January 1). 4) Lake-wide seasonal minimum (days after September 1). 5) Elevation Difference between Upper and Lower Emergent Extent based on Water Level model (Painter & Keddy, 1992). (Upper extent uses average water level surrounding seasonal peak of growing season (e.g., May, June, July average). Upper extent follows this value for rising levels and stays at the highest for 12 years after levels drop and then within 6 years meets the water level. Lower extent uses the mean water level in September. Lower extent follows mean September levels as they drop. As levels rise, it takes 3 years to move up to meet mean September levels.)	C.R.(4861)
4519	Climate Change: Number of Extreme Storms	For land areas adjacent to the Great Lakes, total number of "extreme storms", per year during ice-free and ice-break-up periods on the Great Lakes.	Yes
4520	Development Adjacent to Representative Wetlands		No
4521	Buffers and Land Use Adjacent to Coastal Wetlands	Sum of a weighted score of adjacent land use using km perimeter x weighting factor divided by the total upland perimeter, where the weighting factors are: Built-up = -1; Row Crop = -0.5; Hay and pasture = - 0.2. Where buffers (idle or wooded): Buffer of >1000 m and Land Use beyond buffer: Urban = 1, Row Crop = 1, Hay and Pasture = 1. Buffer of 250 - 1000 m and Land Use beyond buffer: Urban = 0.25, Row Crop = 0.5, Hay and Pasture = 0.8. Buffer of 50 - 250 m and Land Use beyond buffer: Urban = 0.1, Row Crop = 0.2, Hay and Pasture = 0.5. Buffer of 20 - 50 m and Land Use beyond buffer: Urban = 0.05, Row Crop = 0.1, Hay and Pasture= 0.25.	C.R.(7054)

Ind. [illegible]	Indicator name	Measure	[illegible]
4522	Upstream Buffers and Agricultural Land Use		No
4523	Inflow Water Quality: Invertebrate Indices	Area-weighted total of each bioMAP for streams (river mouth wetlands) and Reynoldson's Nearshore Index (open shore wetlands), and possibly on-site turbidity.	No
4524	First Emergence of Indicator spp or Ice Duration	Average emergence of an indicator species; average duration of ice cover.	C.R.(4857,4858)
4525	Quantity and quality of wetlands		No
4526	Quantity and quality of wetlands		No
4527	Quantity and quality of particular habitat		No
4528	Quantity and quality of particular habitat types (e.g. wetlands and spawning beds for desirable native species)		No
4529	Areal Extent of Wetlands (meadow-emergent area)		No
4530	Wetland Extent & Type Diversity (C.2)	Changes in aerial extent and diversity of vegetation types using aerial photos	No
4531	Hexagon-wide Areal Extent of Wetlands		No
4532	Wetland size, abundance		No
4533	Wetland habitat	Number and area	No
4534	Size, Position, and Number of Great Lakes Coastal Wetlands		No
4535	Wetland Size, Abundance, and Susceptibility to Threats Along its Border		No
4536	Areal Extent of Wetland Type		No
4537	Acres of shoreline wetlands with diverse submergent and emergent macrophyte growth that can provide spawning habitat for fish		No
4538	Changes in Area of Habitats or Vegetation Types Over Time		No
4539	Average Area per Wetland		No
4540	Area of relative % area of physical features of watershed based on mapping		No
4541	Number of Wetlands/Unit Area		No
4542	Mapping: Wetland Spatial Configuration		No
4543	Patch Size and Perimeter-to-Area Ratio	Measurements of patch areas and perimeters from aerial photos (GIS for large areas)	No
4544	Fractal Dimension (index of complexity of shapes on the landscape)	Calculation involving perimeter and area for patches on a digitized map	No
4545	Shape Index (perimeter vs perimeter of circle the same area)		No
4546	Patton's Diversity Index	A measure of the amount of edge within an area of given size from aerial photos	No
4547	Compliance with protection of wetlands		No
4548	Number of regulations relating to habitat protection		No
4549	Protection of the Collingwood Wetland Complex		No
4550	Amount of protected spaces versus total area		No
4551	Percent of land covered by historical property protection		No
4552	Habitat loss or restoration		No
4553	Rates of loss of particular habitat types		No

[illegible]	Indicator name	[illegible]	SOLEC Indicator?
4554	Loss in habitat/wetlands quality & quantity		No
4555	Acres restored to wetland condition - net gain		No
4556	Amount of habitat enhancement remediation		No
4557	Gains in habitat/wetlands quality & quantity (areas protected)		No
4558	Range of expansion or reduction of exotic and native species		No
4559	A Habitat Index based on concept of IBI (Index of Biotic Integrity)		No
4560	Resilience - time of recovery of system health following an extreme event/occurrence		No
4561	Interspersion of wetland vegetation and open water (wetland spatial config. - interspersion & water depths)		No
4562	Habitat Proportions (Cover Types)	Mapping and determining proportions of various land use or vegetation cover types in a landscape using remotely sensed data	C.R.(4521)
4563	Fish and wildlife habitat		No
4564	Presence of suitable fish habitat		No
4565	Quantity and quality of habitat throughout the life cycle for critical components of the food web; information about productivity and submerged vegetation may be useful		No
4566	Quantity and quality of habitat throughout the life cycle for critical components of the food web		No
4567	Effect of exotic species		No
4568	Measure of habitat connectiveness (roads, fences, canals, etc.)		C.R.(4521)
4569	Gamma Index of Network Connectivity	Ratio of links in a network to the maximum possible number of links in that network from remotely sensed data	No
4570	Structural Diversity (# veg communities/unit area)		No
4571	Abundance, Diversity, & Species Composition of Vegetation (C.3)	Other metrics: aerial cover, species richness, relative abundance, relative dominance, importance values, diversity, presence/ absence of indicator species, & spatial patterning	No
4572	Extent of submerged aquatic vegetation (distribution)		No
4573	Vegetation Structure		No
4574	Linear Classification & Physical Structure of Habitat	Vertical vegetation profile	No
4575	Permanent vegetation plots		No
4576	Biomass (or production) size spectrum		No
4577	Plant community characteristics (dominance & diversity of indicator species)		No
4578	Changes in Plant Community Characteristics		No
4579	Status of plant communities		No
4580	Status of Plant Communities		No
4581	Productivity/ Population Viability - Plants:	Pitcher's Thistle in low dunes, Lake Huron Tansy	No
4582	Plant performance		No
4583	Status of individual plant species		No
4584	Status of Individual Plant Taxa		No
4585	Leaf Area, Solar Transmittance, & Greenness	Changes in canopy characteristics (e.g., premature leaf drop and yellowing of leaves) and solar transmittance	No
4586	Algae blooms		No
4587	August diatom to blue green algae ratio		No

Ind. code	Indicator name	Measure	SOLEC Indicator?
4588	Chlorophyll a (as indicator of nuisance algal growth)		No
4589	Number of species present from a selected list of conservative wetland obligate marsh species		No
4590	Floristic Quality Assessment		No
4591	Number of species present from a selected list of weedy marsh species	Selected list includes: flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pond weed	No
4592	Index of amount and extent of plant detritus (depth of litter above soil)		No
4593	Marsh Monitoring Program (presence of indicator bird and amphibian species)		No
4594	Results of Breeding Bird Survey		No
4595	Biodiversity Measurements		No
4596	Biotic Community Indices		No
4597	Shannon and Simpson Index		No
4598	Changes in Richness - types of organisms with respect to air/water/land interfaces		No
4599	Species Richness and Berger-Parker		No
4600	Species richness (maintain healthy commercial and recreational fisheries)		No
4601	Species Diversity (alpha, community) (wildlife)		No
4602	Status of basin diversity		No
4603	Regional Diversity (Beta, ecosystem)		No
4604	Changes in Faunal Community Characteristics		No
4605	Integrity of biotic communities		No
4606	Percentage of optimum population density - specific species		No
4607	Presence and relative abundance of key aquatic species		No
4608	Change in keystone or unique species		No
4609	Changes in unique species		No
4610	Demographics: Animals	Age structure, sex ratio, fertility, mortality, survivorship, and dispersal of keystone species	No
4611	Presence and abundance of selected key species within the food web, including a top predator, a mid-trophic level species, and a species at the food base		No
4612	Productivity of certain species - bald eagle, black bear		No
4613	Trophic structures and flux / Number/abundance/status of species representing various trophic levels or guilds		No
4614	Wildlife populations	Species and population	No
4615	Self-sustaining indigenous species, survival, growth, and food habits		No
4616	Presence of Rare, Threatened, or Endangered Species	Selected list includes: Wood Turtle, Blanding's Turtle, W. and N. Ribbon Snake, Queen Snake, E. Massasauga	No
4617	Number and abundance of endangered native species, incl. fish, waterfowl, plants and invertebrates		No
4618	Threatened or endangered species or habitats		No
4619	Population density of provincially significant bird species		No
4620	Population Characteristics of Economically or Socially Valuable Wetland Species		No

Ind. code	Indicator name	Measure	SOLEC indicator?
4621	Presence of Characteristic Species with Narrow Environmental Tolerances		No
4622	Status of Species Typical of a Great Lakes Wetland		No
4623	Detection of new species and establishment of self-sustaining populations		No
4624	Natural reproduction		No
4625	Costs of exotic species		No
4626	Presence and abundance of non-indigenous species		No
4627	Status of Exotic Species		No
4628	Native species loss (# native species)		No
4629	Rates of extinction		No
4630	Number and abundance of native species vs introduced or invading species		No
4631	Non-native species (stressor and effect)		No
4632	Cumulative number and abundance of exotic species introduced		No
4633	Presence and Abundance of Invasive Species		No
4634	Population densities of wildlife including waterfowl		No
4635	Relative Abundance: Animals	Presence of certain water bird species; usefulness of other classes of animals being evaluated	No
4636	Migrating waterfowl counts		No
4637	Number of pairs of colonial waterbirds		No
4638	Population size		No
4639	Reproductive potential (egg size, clutch or brood size)		No
4640	Productivity (young produced and raised to independence)		No
4641	Neotropical bird abundance and diversity		No
4642	Productivity Metrics - Birds	Bald Eagle, 1200 northern breeding pairs – minimum production of 1.0 young per nest; terns, Black-crowned Night-Heron, cormorants – nest production	No
4643	Stress Resistance - Birds	Bald Eagles (for northern Lake Michigan), terns, Black-crowned Night-Herons – genetic diversity, disease incidence, immune function, stress biomarkers	No
4644	Age structure of the population		No
4645	Productivity Metrics - Insects	Biomass by species or guild (emergent, sediment-dwelling, surface, etc.)	No
4646	Amphibian abundance, species richness, and species composition		No
4647	Productivity Metrics - Amphibians	# of Mud Puppy egg masses and % hatching; # of larvae and survival, # of adults	No
4648	Stress Resistance - Amphibians	Mud Puppy – genetic diversity, disease incidence, immune function, stress biomarkers	No
4649	Amphibian Assemblage Diversity		No
4650	Productivity Metrics - Reptiles	# of Snapping Turtle eggs and # of Painted Turtle eggs; # of adult Snapping Turtles and # of adult Painted Turtles; incidence of dead embryos and deformities	No
4651	Stress Resistance - Reptiles	Snapping Turtles and Painted Turtles – genetic diversity, disease incidence, immune function, stress biomarkers	No
4652	Reptile Assemblage Diversity		No
4653	Productivity/ Population Viability - Mammals	Mink – # of offspring and survival, incidence of dead embryos and deformities	No
4654	Stress Resistance - Mammals	Mink – genetic diversity, disease incidence, immune function, stress biomarkers	No
4655	Ungulate range in the Lake superior basin		No
4656	Number and saturation of niches present		No
4657	Faunal indicators of disturbed habitat		No

Ind. code	Indicator name	Measure	SOLEC Indicator?
4658	Population Survival & Mortality		No
4659	Benthic invertebrates (avoid destructive land-water linkages)		No
4660	Shift in oligochaete assemblages & midges, fingernail clams, mayflies, amphipods, indicative of eutrophic environment to mesotrophic environment		No
4661	Benthos		No
4662	Acute and chronic toxic effects on benthic community absent		No
4663	Bioassay of benthic community show end points comparable to controls		No
4664	Benthic biomass ranging from 25 to 50 g/m wet weight of benthos		No
4665	Population densities of mesotrophic species		No
4666	Benthic community structure not significantly different from control sites of desirable physical and chemical characteristics		No
4667	Sediment Particle Size Distribution		No
4668	Aquatic Invertebrate community - multiple metrics		No
4669	Aquatic insect emergence rate (# tax & indiv. / unit time)		No
4670	Deviation from expected benthic community		No
4671	Paleoindicators		No
4672	Macroinvertebrate Abundance, Biomass, & Species Composition		No
4673	Soil & Aquatic Microbial Community Structure		No
4674	Reach specific & basin-wide fish assemblage assessment: species composition, relative abundance, movement, critical habitat identification		No
4675	Species: Northern Pike, Yellow Perch, Brown Bullhead		No
4676	Fish Community Stability		No
4677	Shift from a fish community indicative of eutrophic environment to a self-sustaining community		No
4678	Ratio biomass piscivores to prey fish biomass		No
4679	Proposed nearshore biomass (kg/ha): piscivores 40-60; specialists: 70-100; generalists 30-90		No
4680	Fraction of salmonine production comprising naturally produced fish		No
4681	Balanced fishery and nutrients		No
4682	Increase the (fish) species richness from 4 to 6-7 per transect		No
4683	Abundance/Biomass (fish)		No
4684	Species Abundance/Diversity (fish)		No
4685	Diversity (fish)		No
4686	Pelagic: Benthic Ratio (fish)		No
4687	Increase the native (fish) species biomass from 37% to 80-90% of the total biomass		No
4688	Percent Exotics (fish)		No
4689	Percent of Rough Fish (Biomass) in Community		No
4690	Percent Phytophils (fish)		No

Ind. code	Indicator name	Measure	[illegible]
4691	Predator:Prey Ratio (fish)		No
4692	Percent of Turbidity tolerant species in community (fish)		No
4693	Production of yield piscivores		No
4694	Hatchery production		No
4695	Viable recruitment		No
4696	Attain a littoral fish biomass of 200-250 kg/ha		No
4697	Reduce the spatial variability in fish biomass		No
4698	Healthy fish communities present indicating a viable plankton community		No
4699	Fish harvest statistics vs spawning biomass levels		No
4700	Fish harvest statistics vs. spawning biomass levels		No
4701	Fish catch		No
4702	Total standing stock/secondary production (fish)		No
4703	Commercial Fish Catches of Wetland-dependent Species		No
4704	Changes in sediment budgets, nutrient enrichment, toxic chemicals (BioMAP stream benthic index, Reynoldson's nearshore benthic index, % upland-wetland interface that is buffered)		C.R.(4516,4854,4855,4856)
4705	Acid loadings		No
4706	Quality/quantity of dredged material		No
4707	Loss of habitat specific to persistent toxics		No
4708	Model fate and distribution of suspended sediment/contaminant		C.R.(4516)
4709	Contaminant fate model - TOXIWASP		No
4710	Develop/improve DO modeling capabilities - DOSTOC, WASP		No
4711	Bioassays	Laboratory testing of pollutant effects on organisms	No
4712	Fish and wildlife bioassays confirm no significant toxicity from the water column or sediment contaminants / Contaminant levels in wildlife		No
4713	Algal bioassays show no significant differences in toxicity between harbour and control samples		No
4714	Chemical Contaminants in Water & Sediments		No
4715	Field monitoring of water column contaminants		No
4716	Toxins		No
4717	Levels of nutrients and persistent toxic chemicals		C.R.(4854, 4855, 4856)
4718	Concentrations of Nutrients and Toxic Substances		C.R.(4854, 4855, 4856)
4719	Levels of Persistent Toxic Chemicals		No
4720	Concentration of Persistent Toxic Substances in Biota		No
4721	Concentration of persistent toxic substances in biota		No
4722	Chemical Contaminants in Tissues	Contaminant bioaccumulation in plant and animal tissues	No
4723	Contaminant Accumulation (wildlife)		No
4724	Contaminant levels in tissue population growth rates and density in most sensitive species equal to that of control areas		No

Ind. code	Indicator name	Measure	SOLEC indicator?
4725	Toxic contaminants in aquatic organisms		No
4726	Tissue Concentrations of Toxic Chemicals or Malformation in Fish and Wildlife		No
4727	Concentration of contaminants in fish		No
4728	Levels of toxic contaminants in fish		No
4729	White sucker - population characteristics, reproductive success, tumors, EROD/AHH or Caffeine Breath Test, BROD/PROD, Vitamin A stores, DNA damage, Plasma ALAD		No
4730	Abnormalities/Pathology in Brown Bullhead		No
4731	Contaminant Load in Brown Bullhead Fillet		No
4732	Toxic contaminant levels in selected fish species and in selected fish-eating birds		No
4733	Productivity Metrics - Birds:	Herring Gull contaminant levels	No
4734	Bald Eagle abundance and contamination		No
4735	Bald Eagle - population characteristics, reproductive success, chick growth, congenital abnormalities, eggshell thinning, Caffeine breath Test, Vitamin A stores in plasma, Plasma Thyroxine, Plasma ALAD.		No
4736	Contaminant Metrics - Birds	Bald Eagle (for northern Lake Michigan), terns, Black-crowned Night-Heron, cormorants -- concentration of contaminants, enzyme induction assays	No
4737	Herring gull or Black-crowned night heron - population characteristics, reproductive success, chick growth, congenital abnormalities, EROD/AHH or Caffeine breath Test, PROD/BROD, Vitamin A stores, Plasma Thyroxine.		No
4738	Double-crested cormorant - population characteristics, congenital abnormalities, eggshell thinning		No
4739	Contaminants in Feathers		No
4740	Contaminant Metrics - Plants	Pitcher's Thistle in low dunes; Lake Huron Tansy	No
4741	Contaminant Metrics - Amphibians	Mud Puppy -- concentration of contaminants, enzyme induction assays	No
4742	Contaminant Metrics - Reptiles	Snapping Turtles and Painted Turtles -- concentration of contaminants, enzyme induction assays	No
4743	Snapping turtle - Population characteristics, Reproductive success, Congenital anomalies, DNA damage		No
4744	Contaminant Metrics - Mammals	Mink -- concentration of contaminants, enzyme induction assays	No
4745	Mink - Population characteristics, Reproductive success		No
4746	Acetyl Cholinesterase - AChE (sub-organism)		No
4747	ALAD (sub-organism) (blood enzyme)		No
4748	Species health		No
4749	Detoxifying Enzyme Systems (sub-organisms)		No
4750	Species Specific Individual Pathology		No
4751	Gene Frequency		No
4752	Genetic Damage		No
4753	Immuno Assay (sub-organism)		No
4754	species specific Individual Diet		No
4755	Species-specific Individual Body Weight / Condition Index		No

[illegible]	Indicator name	Measurement	[illegible]
4756	Species - specific individual behaviour		No
4757	Natural Biological Stressors (e.g. count # muskrat houses in sample area)		No
4758	Morphological Asymmetry: Animals	Morphological variability in structure such as teeth and bones of bilaterally symmetrical organisms	No
4759	Biomarkers (broad indicator covered more specifically in next 8 indicators)	Organism response to human-induced stresses at the biochemical and cellular level before the stresses produce a detectable response at the organism and population levels	No
4760	DNA Alteration: Adducts	Lab analysis for DNA adducts indicating exposure to chemical(s); with sufficient toxicological information and identification of particular adducts, data obtained may be a diagnostic screening technique for environmental genotoxicity.	No
4761	DNA Alteration:Secondary Modification	Lab analysis for strand breaks in DNA; screening technique for exposure to any genotoxic chemical.	No
4762	DNA Alteration: Irreversible Event	Lab analysis for irreversible DNA alteration; screening technique that indicates subclinical expression of mutagenic damage.	No
4763	Cholinesterase Levels	Lab analysis for neurotoxic chemicals such as organophosphates and carbamates (insecticides).	No
4764	Metabolites of Xenobiotic Chemicals	Lab analysis for certain metabolites of xenobiotic chemicals in animals; confirms that toxicants have ent.ered cells and interacted with molecular targets.	No
4765	Porphyrin Accumulation	Lab analysis of porphyrins; patterns of accumulation may be used to predict action of chemicals within the pathway of heme biosynthesis, which is vital for maintaining adequate blood cell count; PCBs, Pb may disturb porphyrin metabolism in mammals & birds.	No
4766	Histopathologic Alterations	Extensive methodology exists for determination of tissue, cellular and subcellular responses as an indicator of exposure to a variety of anthropogenic pollutants	No
4767	Fish Consumption Advisories for Wetland-dependent Species		No
4768	Certain Health Problems Associated with Consumption Rates of Plants, Fish, or Wildlife from Coastal Wetlands		No
4769	Macrophage Phagocytotic Activity	Lab analysis of uptake of formalin-killed E. coli by macrophages; indicator of immune system capacity to destroy foreign material can serve as a useful sentinel of the health status of environmentally stressed organisms	No
4770	Water column nutrient levels		C.R.(4855, 4856)
4771	Nutrients in Water & Sediments		C.R.(4855, 4856)
4772	Nutrient diffusing substrates/periphyton		No
4773	Field monitoring of water column SOD		No
4774	Algal blooms, which characterize excess nutrient condition		No
4775	Concentration of total phosphorus		C.R.(4856)
4776	Loadings of phosphorus		C.R.(4856)
4777	Changes in recreational activity due to excess phosphorus		No
4778	Ambient phosphorus concentrations		C.R.(4856)
4779	Ambient phosphorus concentration in selected areas of the Great Lakes		C.R.(4856)
4780	Tributary nitrates concentration		C.R.(4780)
4781	Ratio of nitrogen to phosphorus		No
4782	Dissolved oxygen standard (nearshore)		No
4783	Costs for additional mitigation of nutrient loadings for increased point and non-point source control		No
4784	Set initial and final goals of phosphorus, ammonia and suspended solids net loading targets (kg/d)		C.R.(4516, 4856)

Ind. code	Indicator name	Measure	[illegible]
4785	Nutrient balance (ratio of ammonia & nitrates to total N, of SRP to total P at outlet and inlet)		No
4786	Standing Stock of Major Nutrients (CNP analysis of biomass)		No
4787	Sediment Nutrient Constituents		No
4788	Turbidity		C.R.(4516)
4789	Water quality of harbour and tributary streams		C.R.(4516, 4854, 4855, 4856)
4790	Aquatic Conditions, Diurnal DO/pH, Alkalinity, Temperature, Turbidity & (P/R)		No
4791	Organic Matter & Sediment Accretion (C.1)	Accumulation of both mineral and organic matter in wetlands	No
4792	Drainage (% original wetland drained within 1 km of 1997 boundary)		No
4793	Filling (% of 1955 extent that is filled)		C.R.(4521)
4794	Land use adjacent to wetland		C.R.(4521)
4795	Adjacent Land Use		C.R.(4521)
4796	Land-use Characteristics in the Vicinity of Coastal Wetlands		C.R.(4521)
4797	Changes in land use		C.R.(4521)
4798	Percent Land Use Classes within Hexagon		No
4799	Land uses and land-use practices, including the nature and extent of riparian vegetation, and information about land use zoning and watershed management plans		No
4800	Land-use changes, encroachment, development		C.R.(4521)
4801	Land Use Changes Upstream in the Watersheds of Coastal Wetlands with Inflowing Tributaries		No
4802	Landscape patterns		No
4803	Landscape Pattern (broad indicator covered more specifically in next 6 indicators)	Landscape indicators, calculated from remote sensing, describing the spatial distribution of physical, biological, and cultural features across a geographic area	No
4804	Contagion or Habitat Patchiness	Land-use and vegetation-cover data to calculate this indicator would be provided by EMAP-characterization	C.R.(4521)
4805	Landscape Stressors		C.R.(4521)
4806	Land form and distributary sensitivities; satellite imagery of flooding extent		No
4807	Encroachment/development basin-wide		No
4808	Land-use Changes, Encroachment/ Development Basin-wide		No
4809	Non-point source urban stormwater best management practices		No
4810	Roads (length of roadside abutting wetland)		C.R.(4521)
4811	Hexagon-wide Road Density		No
4812	Non-point source agricultural best management practices		No
4813	Restoration of agricultural land to fallow land		No
4814	Measures of stream-side buffers		No
4815	Riparian vegetation response modeling		No
4816	Buffer zones/forestry clear cutting practices - implications for aquatic and riparian communities		C.R.(4521)

[illegible]	Indicator name	[illegible]	[illegible]
4817	Shoreline Modification (% of shoreline-wetland interface that is modified)		C.R.(4521)
4818	Diking (% of total wetland area that is diked)		C.R.(4521)
4819	Littoral shorelines development		C.R.(4521)
4820	Modified shorelines (to provide cover for fish and wildlife)		C.R.(4521)
4821	Number of engineering land/water interfaces, such as hardened shorelines, dams, weirs and diversions		C.R.(4521)
4822	Number and extent of engineered land/ water interfaces, such as hardened shoreline (breakwalls), dams weirs, and diversions		C.R.(4521)
4823	Human-Use (proximity to channel used by motor boats, existing visitor statistic)		No
4824	Recreational Opportunities		No
4825	Proximity to Navigable Channels		No
4826	Proximity to Recreation Boating Activity		No
4827	Proximity to Navigable Channels and Recreational Boating Activity		No
4828	Dredging (distance to nearest)		No
4829	Land-use planning zoning, re-zoning		No
4830	Amendment of Official Town Plan (for habitat restoration)		No
4831	Number of Employed Persons in Activities Directly or Indirectly Related to Coastal Wetlands		No
4832	Quantity/quality of stream base flows		C.R.(4516)
4833	Quantity and quality of stream base flow		C.R.(4516)
4834	Sediment Supply and Transport (local expertise rating relative levels at each site)		C.R.(4516)
4835	Sediment Supply Characteristics		C.R.(4516)
4836	Streamflow/sedimentation (avoid destructive land-water linkages)		C.R.(4516)
4837	Accessible stream length		No
4838	Hydrologic Connectivity		No
4839	Hydrologic Connectivity with the Lake as Determined by the Presence of Dike Structures or Continuous Natural Barriers		No
4840	Annual Mean Water Level (from nearest station / level at time of fieldwork)		C.R.(4518)
4841	Water Level Regulation (years since regulated)		C.R.(4518)
4842	Hydroperiod	Number of days of inundation per year	No
4843	Water level fluctuation		C.R.(4518)
4844	Water-level Monitoring		C.R.(4518)
4845	Flooding and Dewatering of Wetland		No
4846	Monitor representative flow discharge, depth and velocity		No
4847	Model flow discharge, depth and velocity		No
4848	Ice and Storms (local knowledge to rate conditions at each site)		C.R.(4519, 4858)

Ind. code	Indicator name	Measure	SOLEC Indicator?
4849	Climate change (water depth/from nearest climate station their annual trend indicator for temperature compared to historical standard)		C.R.(4857, 4858)
4850	Protection from erosive forces		No
4851	Protection from Erosive Forces		No
4852	Changes in the Status of Protective Barriers such as Sand Spits or Barrier Beaches		No
4853	Incidents of spills, accidents, releases relating to use and transport of human controlled and human synthesized products		No
4854	Water Quality: Chlorides Flowing Into Coastal Wetlands	Average concentration of chlorides in all existing monitoring sites just upstream of coastal wetlands	No
4855	Water Quality: Nitrates Into Coastal Wetlands	Concentration of nitrate in all existing monitoring sites just upstream of coastal wetlands. Add average atmospheric loading using LRTAP monitoring?	C.R.(4860)
4856	Water Quality: Total Phosphorus Flowing Into Coastal Wetlands	Concentration of Total Phosphorus in all existing monitoring sites just upstream of coastal wetlands.	C.R.(4860)
4857	Climate Change: First Emergence of Water Lilies in Coastal Wetlands	The number of days after January 1 of first sighting of white on a water lily blossom.	Yes
4858	Climate Change: Ice Duration on the Great Lakes	Maximum percentage of Great Lakes area covered by ice each year.	Yes
4859	Reproductive output of mink	Measure DNA of mink tissue and scats collected in spring and fall.	No
4860	Nitrate and Total Phosphorus Into Coastal Wetlands	Concentration of nitrate and total phosphorus just upstream from, or in a set of, Great Lakes coastal wetlands.	Yes
4861	Water Level Fluctuations	For each lake: 1) Mean lake level; 2) Lake-wide annual range in monthly averages; 3) Lake-wide seasonal peak (days after January 1); 4) Lake-wide seasonal minimum (days after September 1); and 5) Elevation Difference between Upper and Lower Emergent Vegetation Extent based on Water Level model.	Yes
7000	Urban Density	Human population per square kilometre of existing and proposed development areas. Total area is adjusted to exclude parks and other designated greenspace.	Yes
7001	Efficient urban density	Non-residential density	C.R.(7000)
7002	Land Conversion	Percent change in land use type, including agriculture, urban development, and forest, marsh or other natural cover.	Yes
7003	Non-Agriculture land conversion	acres of land converted annually	C.R.(7002)
7004	Economically viable communities - downtown	vacant commercial locations	C.R.(7000, 7043)
7005	Economically viable communities-rural	vacant buildings	C.R.(7043)
7006	Brownfield Redevelopment	Total acreage of redeveloped brownfields.	Yes
7007	Resource Use	Energy/water per capita	C.R.(7056, 7057)
7008	Solid waste generation	tons of waste per capita	C.R.(7007)
7009	Water use per capita	litres per day per capita	C.R.(7007)
7010	Wastewater discharge	litres of wastewater per capita	C.R.(7007)
7011	Pollution Prevention	# of waste reduction programs	No
7012	Mass Transportation	Percent of commuters using public transportation.	Yes
7013	Traffic Congestion - cost	Average commuting cost per capita	C.R.(7012)
7014	Mass Transit	% commuters on public transit	C.R.(7012)
7015	Efficient transportation	% of goods moved by fixed link or water	C.R.(7012)
7016	Health care expenditures	dollars spent per capita	No
7017	Pollution Levels	Air index, wastewater and solid waste per capita	C.R.(7058, 7059, 7060)
7018	Beach closings	% days that beaches are closed	C.R.(7017)
7019	Environmental land legacies	# landfills and other sites	C.R.(7006)
7020	Water discharge quality	concentration of contaminants	C.R.(7017)
7021	Environmental illness and mortality	% change in mortality and morbidity	No
7022	Fish advisories	number of restrictions	C.R.(7017)
7023	Outdoor recreation - opportunity	% developed land available for recreation	C.R.(7042)
7024	Outdoor recreation	average % hours spent on leisure	C.R.(7042)

Ind. code	Indicator name	Measure	SOLEC indicator?
7025	Crime rate and social fabric	% change in crimes	C.R.(7042)
7026	Traffic accidents	% change in accidents	C.R.(7012, 7042)
7027	Loss of Natural Features	% of land protected, % forest change, status of breeding birds and other endemic species	No
7028	Sustainable Agricultural Practices	Number of Environmental and Conservation farm plans in place.	Yes
7029	Non-agriculture land loss	acres of natural land lost	C.R.(7027)
7030	Wildlife loss	population losses	C.R.(7027)
7031	Forest clearing	acres clear cut	C.R.(7027)
7032	Forest restoration	acres successfully replanted	C.R.(7027)
7033	Mineral extraction	new acres used for mining	C.R.(7027)
7034	Fisheries pressure	% of biomass harvested	C.R.(7027)
7035	Wildlife pressure	% of wildlife stock harvested	C.R.(7027)
7036	Land hardening	# acres paved or permanently covered	C.R.(7027)
7037	Chemical use - agricultural	Tons pesticide and fertilizer used	C.R.(7017)
7038	Chemical use - non-agricultural	Tons of pesticide and fertilizer use - non-agricultural	C.R.(7017)
7039	Conservation practices	number of acres using conservation	C.R.(7028, 7017,7027)
7040	Contaminated areas	acres contaminated by landfills and other sites	C.R.(7027, 7006)
7041	Cottage and second home development	# of new second homes	C.R.(7002, 7027)
7042	Aesthetics	Amount of waste and decay around human activities.	Yes
7043	Economic Prosperity	Unemployment rates within the Great Lakes basin.	Yes
7044	Public Infrastructure	Infrastructure and facility investments	C.R.(7043)
7045	Cultural Heritage	Preservation of cultural heritage resources	C.R.(7042)
7046	Population Change	Growth or decline in urban or rural areas	C.R.(7000, 7042,7043)
7047	Aboriginal Communities	Number and extent in the Basin	C.R.(7042)
7048	Biodiversity	Changes in areas of natural/semi-natural habitats	C.R.(7027)
7049	Beauty/Aesthetics	Number of comm. environment improvement schemes	C.R.(7042)
7050	Building Permits	Number of permits issued annually	C.R.(7000, 7002)
7051	Human Impact	Measure of damage or remediation	C.R.(7017, 7002,7007)
7052	Reinvestment of Natural Capital	Social resources to maintain natural resources	C.R.(7043, 7007)
7053	Green Planning Process	Number of municipalities with environmental and resource conservation management plans.	Yes
7054	Ground surface hardening	Percentage of land that is covered by buildings, roads, parking lots and other hardened surfaces.	No
7055	Habitat Adjacent to Coastal Wetlands	Land use within 1 kilometre (km) inland of a representative set of coastal wetlands, measured as a weighted score determined by multiplying the wetland perimeter (km) in each land use by an associated weighting factor and dividing by the total upland perimeter (km) of the wetland.	Yes
7056	Water Withdrawal	Water use per capita in the Great Lakes basin.	Yes
7057	Energy Consumption	Energy use in kilowatt hours per capita.	Yes
7058	Ground Level Ozone	Total number of days the ground level ozone standard is exceeded on an annual basis in the Great Lakes region.	C.R (4176)
7059	Wastewater Pollution	Loadings of metals, phosphorus, BOD and organic chemicals that are released by municipal sewage treatment plants and industrial direct dischargers, into water courses in the Great Lakes basin.	Yes
7060	Solid Waste Generation	Amount of solid waste generated per capita (tons and cubic metres).	Yes
8000	Threatened species	% of known bird species threatened	No
8001	Threatened species	% of known mammal species threatened	No
8002	Threatened species	% of known reptile/amphibian species threatened	No
8003	Threatened Species	% of vascular plant species threatened	No
8004	Protected areas	number of sites	No
8005	Protected area	Total size	No
8006	Protected area	% of territory	No
8007	Protected area	Per capita: km2/1000 inhabitants	No
8008	Key species	Presence/abundance of key species	No
8009	Habitat types	Quantity and quality of habitat types	No

Ind. code	Indicator name	Measure	SOLEC indicator?
8010	Endangered species	Number and abundance of endangered species	No
8011	Biological community integrity	Cumulative number and abundance of exotic species	No
8012	Contaminant levels	Toxic contaminant levels in selected species	No
8013	Habitat quality	Quantity/quality of habitat for critical food web	No
8014	Stream flows	Quantity/quality of stream base flow	No
8015	Engineered shorelines	Number/extent of engineered land/water edges	No
8016	Riparian vegetation	Nature/extent of riparian vegetation	No
8017	Land use	Land use zoning	No
8018	Exotic species	Range expansion or reduction of exotic/native spp.	No
8019	Exotic species	Establishment of new self-sustaining populations	No
8020	Biological community integrity	Rates of extinction of species	No
8021	Exotic species	Warning/prevention/control programs in place	No
8022	Productivity of selected species	Productivity of bears, bald eagles	No
8023	Habitat connectedness	Number of barriers - roads, rail, canals, etc	No
8024	Habitat restoration	Acres of habitat type restored	No
8025	Habitat disturbance	Quantity/quality of dredged materials	No
8026	Species richness	Changes in richness or types of organisms	No
8027	Change in keystone or unique species	Population change of selected species	No
8028	Optimum population density	% of optimum density for selected species	No
8029	Landscape patterns	Changes in patterns of land use in each ecoregion	No
8030	Integrity of biotic communities	Extent of community stability under stress	No
8031	Significant bird species	Population density of significant bird species	No
8032	Density of worms	Quantity/species diversity of earthworms	No
8033	Physical features distribution	Area or % of physical features	No
8034	Habitat index	Habitat index based on IBI concept	No
8035	Habitat regulations	Number of regulations for habitat protection	No
8036	Sensitive habitats	% of sensitive habitats protected	No
8037	Habitat enhancement	Amount of habitat enhancement or remediation	No
8038	Permanent vegetation plots	Changes in composition/health of vegetation	No
8039	Colonial waterbirds	Number of pairs of colonial waterbirds by species	No
8040	Wildlife reproductive potential	Egg size, clutch or brood size for selected spp	No
8041	Wildlife productivity	Number/% of young raised to independence	No
8042	Wildlife age structure	Age structure of selected wildlife populations	No
8043	Wildlife contaminants	Contaminant levels in robust wildlife species	No
8044	Wildlife niches	Number and saturation of niches present	No
8045	Native/exotic species	Number/abundance of native vs exotic species	No
8046	Bald eagle recovery	Abundance and contamination of bald eagles	No
8047	Fish-eating birds	Contaminant levels in young gulls and cormorants	No
8048	Ungulate range	Proportion of historical range or range shifts	No
8049	Amphibian populations	Status and trends of amphibian populations	No
8050	Marsh birds	Status and trends of marsh bird populations	No
8051	Mink contamination	Contaminant loads in mink carcasses	No
8052	Neotropical birds	Abundance and diversity of neotropical birds	No
8053	Streamflow/sedimentation	Trends in streamflow patterns/sediment discharge	No
8054	Benthic invertebrates	Density/richness of invertebrates in streams/lakes	No
8055	Forest fragmentation	% closed-canopy, mean patch size, variability	No
8056	Accessible stream length	Total length or % of streams below first barrier	No
8057	Forest diversity	% forest types/total area and historical extent	No
8058	Forest diversity	% and extent of forest type and age class	No
8059	Protected forest	Area, % and representation in protected areas	No
8060	Species decline	Number of species occupying <50% of full range	No
8061	Forest conversion	Area of forest permanently converted to urban, etc	No
8062	Vegetation structural diversity	# of habitat types/unit area	No
8063	Shape index	Perimeter of habitat/perimeter of same area circle	No
8064	Plant community characteristics	dominance/diversity of indicator/rare/sensitive sp	No
8065	Floristic Quality Assessment	Natural quality scores based on total species list	No
8066	BioMAP	Stream benthic invertebrates rated for sensitivity	No
8067	Retention of shoreline species/communities	Rate of loss of selected species/communities	No
8068	Wildlife population viability	Pitcher's thistle, L. Huron tansy, dwarf lake iris	No
8069	Wildlife population viability	Insect biomass by species or guild	No

Ind. code	Indicator name	Measure	SOLEC indicator?
8070	Wildlife population viability	# turtle eggs, dead embryos and deformities	No
8071	Wildlife population viability	Nest production of eagles, gulls, night herons,	No
8072	Wildlife population viability	mink # offspring, survival, dead/deformities	No
8073	Wildlife contaminants	Concentrations in turtles, fox snake, mink	No
8074	Wildlife contaminants	Concentrations in osprey, eagles, cormorant, terns	No
8075	Wildlife stress resistance	Genetic diversity, disease incidence, in species	No
8076	Wildlife stress resistance	Immune function, stress biomarkers in species	No
8077	Wildlife population viability	Species richness and Berger-Parker	No
8078	Wildlife population viability	Shannon and Simpson index	No
8079	Wildlife population viability	Amphibian assemblage diversity	No
8080	Wildlife population viability	Swink and Wilhelm Native Index for plants	No
8081	Wildlife population viability	Results from breeding bird surveys	No
8082	Habitat distribution	Area of cropland/pasture, woodland/woodlots	No
8083	Habitat distribution	Area of urban/industrial, golf courses	No
8084	Significant habitat types	Area of habitats designated by gov'ts or NGOs	No
8085	Lichen distribution	# and types of lichen species present	No
8086	Shoreline development	% of shoreline developed/undeveloped	No
8087	Public access	% of shoreline length open to public access	No
8088	Degree of roadlessness	Total length of roads within 3 km of shore	No
8089	Small watershed quality	% imperviousness	No
8090	Small watershed quality	# of mature trees per acre	No
8091	Reptiles/amphibians	Population trends, species diversity	No
8092	Reptiles/amphibians	# of species with deformities over 10% population	No
8093	Threatened species	Species added/removed; up/downgraded	No
8094	Threatened species	Recovery plans completed/needed	No
8095	Threatened species	Species on track to recovery/getting worse	No
8096	Development pressure	# housing units, hotel rooms built	No
8097	Development pressure	Real estate land values	No
8098	Development pressure	Population density	No
8099	Development pressure	Trends in #, type of building permits	No
8100	Development pressure	Lot sizes along lakeshore	No
8101	Wildlife population viability	Density of deer populations	No
8102	Forest quality	% land base in conifer vs aspen	No
8103	Climate change	Changes in sand spit patterns on Apostles	No
8104	Special communities health	Heinz emerald dragonfly	No
8105	Special communities health	Eastern hemlock population trends	No
8106	Special communities health	Winter wren, veery, prairie warbler, wood pewee	No
8107	Agricultural land use	Area of farmland within 5, 10 km of shoreline	No
8108	Agricultural land use	Farmland as % of total land	No
8109	Agricultural land use	% of cropland receiving fertilizer	No
8110	Agricultural land use: cropland intensity	Cropland as percentage of total land area, and trends over time. An alternative measure is cropland as percentage of total farmland, which is the common practice of the agricultural community. But it is useless in this latter form unless indicator 8111 (farmland intensity) is simultaneously available.	No
8111	Agricultural intensity	Farmland as percentage of total land area, and trends over time.	No
8112	Land use cover	% land cover by land use category	No
8113	Similarity to climax vegetation	Degree of similarity to potential (climax) vegetation	No
8114	Habitat Fragmentation	The pattern of natural habitat remaining within ecoregions/subsections, as measured by 1) area to perimeter ratio; 2) habitat patch size; and 3) percent intact cover.	Yes
8115	Riparian integrity	Extent and distribution of riparian vegetation	No
8116	Ecosystem diversity	% composition by forest type	No
8117	Soil quality/condition	Soil conditions for forest, rangeland, farmland	No
8118	Species abundance	Relative population levels of common species	No
8119	Species condition	Tree stand condition - insects, disease	No
8120	Status of endangered and threatened species	Known presence/absence, population levels	No
8121	Status of unique ecosystems/habitats	Presence/absence, condition	No
8122	Status of vulnerable ecosystems/species	presence/absence, condition	No
8123	Ecosystem services	Timber, carbon sequestration, recreation	No

Ind. code	Indicator name	Measure	SOLEC Indicator?
8124	Available resources	land area available for recreation, hunting, etc	No
8125	Pollution of terrestrial ecosystems	Air pollution, accumulation of toxics	No
8126	Soil erosion	Soil erosion potential, rates	No
8127	Urban sprawl	Developed lands, nighttime lights	No
8128	Nearshore threatened species	Number and proportion of nearshore species ranked as GI-G3 or S1-S3 in the Biological Conservation Database.	C.R.(8161)
8129	Area, Quality and Protection of Lakeshore Communities	Area, quality, and protected status of 12 special lakeshore communities occurring within 1 kilometre of shoreline.	Yes
8130	Habitat distribution	% land cover by habitat type <1km from shore	No
8131	Extent of Hardened Shoreline	Kilometres of shoreline that have been hardened through construction of sheet piling, rip rap and other erosion control shore protection structures. (Does not include artificial coastal structures such as jetties, groynes, breakwalls, piers, etc.)	Yes
8132	Nearshore Land Use	Land use types, and associated area, within 1 kilometre (km) of shore. Land use types could include urban residential, commercial, and industrial, non-urban residential, intensive agriculture, extensive agricultural, abandoned agricultural, closed-canopy forest, harvested forest, wetland and other natural area.	Yes
8133	Lake Level Fluctuations	Range, frequency and seasonal pattern of fluctuations in water levels on each of the Great Lakes.	C.R.(4861)
8134	Nearshore Plant and Animal Problem Species	Type and abundance of plant and animal problem species, including white sweet clover, leafy spurge, spotted knapweed, garlic mustard, white-tailed deer, and Brown-headed Cowbird, within 1 kilometre (km) from shore.	Yes
8135	Contaminants Affecting Productivity of Bald Eagles	1) Concentrations of DDT Complex, PCB, PCDD, PCDF and other organic contaminants and mercury and other heavy metals in Bald Eagle eggs, blood, and feathers; 2) number of fledged young produced; and 3) number of developmental deformities.	Yes
8136	Extent and Quality of Nearshore Natural Land Cover	Percent of natural land cover types within 1 km of the shoreline that meet minimum standards of habitat quality.	Yes
8137	Nearshore Species Diversity and Stability	The type and number of plant and wildlife species, and vegetation regeneration rates within the nearshore area, defined as the area within 1 kilometre (km) of the shoreline.	Yes
8138	Expected diversity	% of sites with >90% expected diversity/population	No
8139	Community / Species Plans	Number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities — those within 1 kilometre (km) of the shoreline — and federally/nationally listed endangered, threatened, and vulnerable species.	Yes
8140	Financial Resources Allocated to Great Lakes Programs	The total amount of dollars spent on an annual basis by federal and state/provincial agencies and non-governmental organizations in each of four areas: Great Lakes research, monitoring, restoration, and protection (including within nearshore lands).	Yes
8141	Shoreline Managed Under Integrated Management Plans	Percent of shoreline managed under an integrated shoreline management plan. An integrated shoreline management plan is one that includes consideration of coastal processes, aquatic habitat, and designates appropriate setbacks, etc. and is incorporated into local planning documents (e.g. a municipal Official Plan).	Yes
8142	Sediment Available for Coastal Nourishment	Measure of stream flow and suspended sediments at the mouth of major tributaries and connecting channels.	Yes
8143	Interior species	Density of interior forest/grassland species	No
8144	Agricultural land use: Key Best Management Practices (BMP)	There are many BMPs. This indicator should be an aggregate of key desirable practices related to (i) cropping and tilling (conservation- or no-tilling, crop rotation, cover crops, grassed waterways, strip or contour cropping, shelterbelts), (ii) use of farm chemicals and manure (decreased use of pesticides and fertilizer per unit area, integrated pest and nutrient management, etc.). At present, the aggregate indicator will be limited to those practices for which adequate data are available. Others (e.g. integrated pest management) should be included as they become available (e.g. through the census). Measures (good, indifferent, bad) include expert value judgments on how to weight the individual practices in the aggregate, and on what constitutes good or bad.	C.R.(7028)
8145	Forest certification	Acreage managed under forest certification	No
8146	Artificial Coastal Structures	The number and type of artificial coastal structures (including groynes, breakwalls, riprap, piers, etc) on the Great Lakes shoreline. Artificial coastal structures include structures that extend into shallow waters at an angle from the shoreline, or are placed offshore for the purpose of breaking the force of the waves. They are distinct from the hardened shoreline works described in indicator 8131, Hardened Shoreline, which modify the shoreline edge itself.	Yes

Ind. code	Indicator name	Measure	SOLEC Indicator
8147	Contaminants Affecting the American Otter	1) Concentrations of heavy metals (e.g., Hg, Pb, Cd) found in hair, blood, liver, and brain of the American otter; and 2) concentrations of DDT and metabolites, PCBs/ PCDFs/PCDDs, Dioxin, and other organic contaminants found in fatty tissues, liver, and blood of the American otter.	Yes
8148	Nearshore endemic species	Number, extent and viability of endemic species populations within 1 kilometre of shore.	C.R.(8161)
8149	Protected Nearshore Areas	The percentage of the Great Lakes shoreline under various levels of protection in six classes as defined by the International Union for the Conservation of Nature (IUCN). The six IUCN classes are 1) strict protection, such as nature reserves and wilderness; 2) ecosystem conservation and recreation, such as national parks; 3) conservation of natural features, such as natural monuments; 4) conservation through active management, such as wildlife management areas; 5) protected landscapes/seascapes; and 6) managed resource protected areas, such as sustainable use areas.	Yes
8150	Breeding Bird Diversity and Abundance	Diversity and abundance of breeding bird populations and communities in selected habitat types, and an avian index of biotic integrity.	Yes
8151	Number, extent and viability of endemic species	Number, extent and viability of endemic species populations basin-wide.	C.R.(8161)
8152	Threatened species	Number and proportion of Great Lakes basin species ranked as GI-G3 or S1-S3 in the Biological Conservation Database.	C.R.(8161)
8153	Areas of land under formal land management plan (not completed)		No
8160	Agricultural Land Use: Livestock density	Number of livestock per unit area, weighted by amount of manure-nitrogen produced per head.	No
8161	Threatened Species	Number, extent, and viability of species ranked as GI-G3 or S1-S3 in the Biological Conservation Database.	Yes
9000	Acid Rain	1) Levels of pH in precipitation in the Great Lakes Basin, and 2) the area within the Great Lakes basin in exceedance of critical loadings of sulphate to aquatic systems, measured as wet sulphate residual deposition over critical load (kg/ha/yr).	Yes
9001	Atmospheric Visibility: Prevention of Significant Deterioration	Percentage of daylight hours per year which have <10 km Visible Range (for relative humidity values < 80% and no observed weather codes from synoptic observations).	No
9002	Exotic Species	This indicator will assess the presence, abundance and distribution of invasive exotic species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. *This indicator is under development.*	Under Consideration

Appendix 3 — Relevancies (or Alternate Indicator Groupings)

The SOLEC list of indicators was developed according to the categories of open and nearshore waters, coastal wetlands, nearshore terrestrial, human health, land use, societal and unbounded. These groupings are convenient for SOLEC reporting, but they represent only one of many ways to organize information about the Great Lakes. Depending on the user's perspective, other groupings will be more convenient or will provide insight to aspects of the Great Lakes that differ from the SOLEC groupings.

Each of the proposed SOLEC indicators has been evaluated by the Indicators Group for relevance to several other organizational categories, and the results are displayed in the attached table. The categories include;

- Indicator Type. Based on the State-Pressure-Human Activity model, each SOLEC indicator has been assigned to the appropriate category. Measurements of contaminants in an environmental compartment are considered a pressure on the ecosystem rather than a measurement of a state condition. There are currently 28 State, 37 Pressure and 15 Human Activity indicators proposed.
- Environmental Compartments. This category sorts the SOLEC indicators by media, i.e., air (6), water (14), land (14), sediments (4), biota (21), fish (13), and humans (14). Fish have been separated from biota as a special case.
- Issues. Environmental management decisions often reflect an attempt to address an issue rather than a medium or geographic location. Specific issues that SOLEC indicators support include toxic contaminants (29), nutrients (12), exotic species (8), habitat (28), climate change (4), and stewardship (11).
- GLWQA Annexes. Several of the annexes of the GLWQA include monitoring and reporting requirements. The proposed SOLEC indicators currently address 10 of the 17 annexes. Annex 11 (Monitoring) is supported if an indicator supports any of the other annexes, and Annex 2 (LaMPs and RAPs) is supported if the indicators address any of the Beneficial Use Impairments.
- GLWQA Beneficial Use Impairments. Under Annex 2 of the GLWQA, fourteen Beneficial Use Impairments are listed for consideration by Lakewide Management Plans and Remedial Action Plans. The SOLEC indicators address to some extent 11 of the 14 listed use impairments.
- IJC Desired Outcomes. The IJC listed nine Desired Outcomes in its report *Indicators to Evalutate Progress under the Great Lakes Water Quality Agreement* (1996). SOLEC indicators address to some extent all nine Desired Outcomes. The many indicators with relevance to the outcomes of Biological Community Integrity and Diversity, and Physical Environment Integrity (including habitat) reflect SOLEC's emphasis on the biotic components of the Great Lakes ecosystem.
- Great Lakes Fish Community Objectives. A series of fish community objectives have been released or are being developed for each of the Great Lakes with the support of the Great Lakes Fishery Commission. Some SOLEC indicators specifically reflect the state of fish communities, and others address related habitat issues.

To facilitate cross referencing of the SOLEC indicators to the alternate categories, a section has been added to each indicator description (Appendix 1) that lists all the applicable categories. This matrix of alternate groupings of SOLEC indicators is also being incorporated into the SOLEC indicators database. Users will be able to retrieve the list of indicators associated with any of the sorting categories.

While the SOLEC indicators are intended to meet the criteria of necessary, sufficient and feasible for SOLEC reporting, no attempt has been made to evaluate the adequacy of the subset of SOLEC indicators that are relevant to any of the alternate organizing categories from the perspective of other users. For example, LaMPs and RAPs are expected to require a greater level of detail and geographic specificity to assess Beneficial Use Impairments than will be provided by the proposed SOLEC indicators. **Suggestions and comments on the relevance of the SOLEC indicators to these or other alternate categories are encouraged.**

Table on following pages.

ID#	Indicator Name	Indicator Type			Environmental Compartments							Great Lakes Issues						SOLEC Groupings[1]								GLWQA Annex[2]				
		State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota (excluding fish & humans)	Fish	Humans	Contaminants & Pathogens	Nutrients	Exotics	Habitat	Climate Change	Stewardship	Open Waters	Nearshore Waters	Coastal Wetlands	Nearshore Terrestrial	Land Use	Human Health	Societal	Unbounded	1 Spec Objctvs	2 LaMPs / RAPs / BUIs	3 Phosphorus	4 Oil - Vessels	5 Wastes - Vessels
	Nearshore and Open Waters Indicators																													
6	Fish Habitat	X				X				X					X			X	X	X							X			
8	Salmon and Trout	X								X		X	X	X	X			X	X								X			
9	Walleye and Hexagenia	X							X	X		X	X	X	X			X	X								X			
17	Preyfish Populations	X								X		X	X	X	X			X	X								X			
18	Sea Lamprey		X							X				X				X	X								X			
68	Native Unionid Mussels	X							X					X				X	X	X							X			
93	Lake Trout and Scud *(Diporeia hoyi)*	X							X	X		X	X	X	X			X								X	X			
101	Deformities, Eroded Fins, Lesions and Tumors (DELT) in Nearshore Fish	X								X		X							X								X			
104	Benthos Diversity and Abundance	X							X			X	X		X			X	X	X							X			
109	Phytoplankton Populations	X							X			X	X	X				X	X								X	X		
111	Phosphorus Concentrations and Loadings		X			X							X					X	X	X						X	X	X		
114	Contaminants In Young-of-the-Year Spottail Shiners		X							X		X							X							X	o			
115	Contaminants in Colonial Nesting Waterbirds		X						X			X						X	X							X	X			
116	Zooplankton Populations	X							X			X	X	X				X	X								X			
117	Atmospheric Deposition of Toxic Chemicals		X		X	X						X						X									o			
118	Toxic Chemical Concentrations in Offshore Waters		X			X						X						X								X				
119	Concentrations of Contaminants in Sediments Cores		X					X				X						X	X								X			
120	Contaminant Exchanges Between Media: Air to Water, and Water to Sediment		X		X	X		X				X						X	X							X				
7059	Wastewater Pollution		X			X						X	X						X							X	X	X		
8142	Sediment Available for Coastal Nurishment	X				X		X							X				X		X						X			
	Coastal Wetland Indicators																													
4501	Coastal Wetland Invertebrate Community Health	X							X						X					X							X			
4502	Coastal Wetland Fish Community Health	X								X				X	X					X							X			
4503	Deformities, Eroded Fins, Lesions and Tumors (DELT) in Coastal Wetland Fish	X								X		X								X							X			
4504	Amphibian Diversity and Abundance	X							X						X					X										
4506	Contaminants in Snapping Turtle Eggs		X						X			X								X						X				
4507	Wetland-Dependent Bird Diversity and Abundance	X							X						X					X							X			
4510	Coastal Wetland Area by Type	X				X	X								X					X							X			
4511	Gain in Restored Coastal Wetland Area by Type			X		X	X								X		X			X							X			
4513	Presence, Abundance & Expansion of Invasive Plants	X							X					X	X					X	X						X			
4516	Sediment Flowing Into Coastal Wetlands		X			X		X							X					X	X					X	X			
4860	Nitrate and Total Phosphorus Into Coastal Wetlands		X			X							X							X							X	X		
4861	Water Level Fluctuations		X			X									X	X				X	X						X			
	Nearshore Terrestrial Indicators[3]																													
8129	Area, Quality, and Protection of Lakeshore Communities	X					X		X						X		X				X						X			
8131	Extent of Hardened Shoreline		X				X								X						X	X					X			
8132	Nearshore Land Use	X					X								X						X	X					X			

GLWQA Annex (con'd)												IJC Desired Outcomes									GLFC Objectives					Beneficial Use Impairments														
6 Shipping / Pollution	7 Dredging	8 Facilities	9 Contingency Plan	10 Hazard. Poll. List	11 Monitoring	12 Pers. Toxic Subs.	13 Non-point Sources	14 Contam. Sed's	15 Airborne Toxic Subs.	16 Groundwater	17 Res. & Devel.	1 Fishability	2 Swimmability	3 Drinkability	4 Healthy Humans	5 Economic Viability	6 Bio. Integ. & Divers.	7 Virt. Elim. PTS	8 Excess Phos.	9 Physical Env. Integ.	Ontario	Erie	Huron	Michigan	Superior	1 F&W Consumption	2 Tainting	3 F&W Pop's	4 Tumors	5 Deformities/Reprod.	6 Benthos	7 Dredging	8 Eutrophication	9 Drinking Water	10 Beach Closings	11 Aesthetics	12 Ag./Indust. Costs	13 Phyto-/Zoo-plankton	14 F&W Habitat	Totals
					X												X			X	X	X	X	X	X														X	17
					X												X				X		X	X	X			X												16
					X												X				X	X	X					X			X									17
					X												X				X	X	X	X	X			X												17
					X												X				X	X	X	X	X			X												14
					X												X														X									10
					X												X				X	X	X	X	X			X			X									19
					X	X											X	X											X											10
					X												X														X									12
					X												X		X																			X		13
					X		X										X		X			X											X	X		X		X		18
					X	X											X	X																						10
					X	X											X	X				X						X		X										14
					X												X																					X		11
					X	X			X		X							X																						11
					X	X												X																						8
	X				X	X		X										X													X	X								13
					X	X		X	X		X							X																						14
					X	X												X	X														X			X				14
					X															X																			X	10
					X		X										X			X											X									10
					X		X										X			X								X											X	12
					X	X	X				X						X	X											X											12
					X		X										X			X								X											X	10
					X	X	X											X																						9
					X												X			X								X											X	10
					X		X										X			X																			X	11
					X		X										X			X																			X	12
					X		X										X																						X	11
					X		X													X																			X	12
					X		X												X														X							10
					X						X						X			X																			X	12
					X												X			X																			X	11
					X															X																			X	9
					X												X			X																			X	10

ID#	Indicator Name	Indicator Type			Environmental Compartments							Great Lakes Issues						SOLEC Groupings[1]								GLWQA Annex[2]				
		State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota (excluding fish & humans)	Fish	Humans	Contaminants & Pathogens	Nutrients	Exotics	Habitat	Climate Change	Stewardship	Open Waters	Nearshore Waters	Coastal Wetlands	Nearshore Terrestrial	Land Use	Human Health	Societal	Unbounded	1 Spec Objctvs	2 LaMPs / RAPs / BUIs	3 Phosphorus	4 Oil - Vessels	5 Wastes - Vessels
8134	Nearshore Plant and Animal Problem Species		X						X					X	X						X						X			
8135	Contaminants Affecting Productivity of Bald Eagles		X						X			X						X	X		X						X			
8136	Extent and Quality of Nearshore Natural Land Cover	X					X								X						X						X			
8137	Nearshore Species Diversity and Stability	X							X					X							X						X			
8139	Community / Species Plans			X					X								X				X			X						
8141	Shoreline Managed Under Integrated Management Plans			X			X										X				X	X		X						
8146	Artificial Coastal Structures		X				X								X				X		X						X			
8147	Contaminants Affecting the American Otter		X						X			X								X	X					X	X			
8149	Protected Nearshore Areas			X			X								X		X				X			X			X			
	Land Use Indicators																													
7000	Urban Density	X					X															X								
7002	Land Conversion		X				X															X								
7006	Brownfield Redevelopment			X			X										X					X								
7012	Mass Transportation		X		X		X									X	X					X								
7028	Sustainable Agricultural Practices			X			X										X					X					X	X		
7053	Green Planning Process			X		X	X										X					X		X						
7055	Habitat Adjacent to Coastal Wetlands	X					X								X					X	X	X					X			
8114	Habitat Fragmentation	X					X								X							X					X			
	Human Health Indicators																													
113	Contaminants in Recreational Fish		X							X		X						X	X				X			X	X			
4081	*E. coli* and Fecal Coliform Levels in Nearshore Recreational Waters		X			X			X			X							X				X			X	X			
4083	Contaminants in Edible Fish Tissue		X							X		X						X	X				X			X	X			
4088	Chemical Contaminant Intake from Air, Water, Soil and Food		X								X	X											X							
4175	Drinking Water Quality		X			X						X	X					X	X				X			X	X			
4176	Air Quality		X		X							X											X			X	o			
4177	Chemical Contaminants in Human Tissue		X								X	X											X			X				
4178	Radionuclides		X		X	X			X			X											X			X				
4179	Geographic Patterns and Trends in Disease Incidence	X									X												X							
	Societal Indicators																													
3509	Capacities of Sustainable Landscape Partnerships			X							X						X							X						
3510	Organizational Richness of Sustainable Landscape Partnerships			X							X						X							X						
3511	Integration of Ecosystem Management Principles Across Landscapes			X							X						X							X						
3512	Integration of Sustainability Principles Across Landscapes			X							X						X							X						
3513	Citizen/Community Place-Based Stewardship Activities			X							X						X							X						
7042	Aesthetics	X									X						X							X			X			
7043	Economic Prosperity	X																						X						
7056	Water Withdrawal		X			X					X						X					X		X						

GLWQA Annex (con'd)												IJC Desired Outcomes									GLFC Objectives					Beneficial Use Impairments														
6 Shipping / Pollution	7 Dredging	8 Facilities	9 Contingency Plan	10 Hazard. Poll. List	11 Monitoring	12 Pers. Toxic Subs.	13 Non-point Sources	14 Contam. Sed's	15 Airborne Toxic Subs.	16 Groundwater	17 Res. & Devel.	1 Fishability	2 Swimmability	3 Drinkability	4 Healthy Humans	5 Economic Viability	6 Bio. Integ. & Divers.	7 Virt. Elim. PTS	8 Excess Phos.	9 Physical Env. Integ.	Ontario	Erie	Huron	Michigan	Superior	1 F&W Consumption	2 Tainting	3 F&W Pop's	4 Tumors	5 Deformities/Reprod.	6 Benthos	7 Dredging	8 Eutrophication	9 Drinking Water	10 Beach Closings	11 Aesthetics	12 Ag./ Indust. Costs	13 Phyto-/ Zoo-plankton	14 F&W Habitat	Totals
					X						X						X			X								X											X	12
					X	X					X						X	X										X		X										14
					X												X			X																			X	9
					X												X											X												8
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					X	X					X						X	X										X		X										14
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					X		X						X		X																				X					13
					X	X						X			X		X	X			X	X	X	X	X	X														20
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					X																															X				7
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ID#	Indicator Name	Indicator Type			Environmental Compartments							Great Lakes Issues						SOLEC Groupings[1]								GLWQA Annex[2]				
		State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota (excluding fish & humans)	Fish	Humans	Contaminants & Pathogens	Nutrients	Exotics	Habitat	Climate Change	Stewardship	Open Waters	Nearshore Waters	Coastal Wetlands	Nearshore Terrestrial	Land Use	Human Health	Societal	Unbounded	1 Spec Objctvs	2 LaMPs / RAPs / BUIs	3 Phosphorus	4 Oil - Vessels	5 Wastes - Vessels
7057	Energy Consumption		X		X						X					X	X					X		**X**						
7060	Solid Waste Generation		X		X		X				X	X				X	X							**X**						
8140	Financial Resources Allocated to Great Lakes Programs			X							X						X							**X**						
[illegible]																														
4519	Climate Change: Number of Extreme Storms		X		X											X				X	X				**X**					
4857	Climate Change: First Emergence of Water Lily Blossoms in Coastal Wetlands		X						X							X				X					**X**					
4858	Climate Change: Ice Duration on the Great Lakes		X			X										X		X	X	X					**X**					
8150	Breeding Bird Diversity and Abundance	X							X						X										**X**		X			
8161	Threatened Species	X							X	X				X	X										**X**		X			
9000	Acid Rain		X		X	X	X					X													**X**	X				
9002	Exotic Species		X						X	X				X											**X**					
86	COUNT	30	36	13	9	19	19	4	24	14	13	29	11	14	27	7	19	21	24	21	18	13	9	15	7	18	49	5	0	0
	[1] Bold X designates the primary SOLEC Grouping for each indicator																													
	[2] o = Some LaMPs /RAPs are incorporating these measures into their plans even though the indicators do not have an associated BUI																													
	[3] #8142 Sediment Available for Coastal Nurishment and #4861 Water Level Fluctuations are also co-grouped with Nearshore Terrestrial Indicators																													

GLWQA Annex (con'd)												IJC Desired Outcomes									GLFC Objectives					Beneficial Use Impairments														
6 Shipping / Pollution	7 Dredging	8 Facilities	9 Contingency Plan	10 Hazard. Poll. List	11 Monitoring	12 Pers. Toxic Subs.	13 Non-point Sources	14 Contam. Sed's	15 Airborne Toxic Subs.	16 Groundwater	17 Res. & Devel.	1 Fishability	2 Swimmability	3 Drinkability	4 Healthy Humans	5 Economic Viability	6 Bio. Integ. & Divers.	7 Virt. Elim. PTS	8 Excess Phos.	9 Physical Env. Integ.	Ontario	Erie	Huron	Michigan	Superior	1 F&W Consumption	2 Tainting	3 F&W Pop's	4 Tumors	5 Deformities/Reprod.	6 Benthos	7 Dredging	8 Eutrophication	9 Drinking Water	10 Beach Closings	11 Aesthetics	12 Ag./ Indust. Costs	13 Phyto-/ Zoo-plankton	14 F&W Habitat	Totals
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																				X																				8
					X												X			X								X											X	10
					X						X						X			X								X											X	13
					X				X											X																				10
																																								5
0	1	0	0	0	58	19	17	2	6	1	11	2	1	1	9	1	37	17	5	30	8	9	8	7	7	2	0	15	2	3	6	1	4	2	1	3	0	3	22	

Appendix 4 — Criteria

SOLEC 98 Indicator Project Goals, Objectives and Criteria

Project Goals: The aim of the SOLEC 98 indicators project is to gather together a list of indicators that will be used by the Parties (to the GLWQA) to report on the health of the Great Lakes basin ecosystem on a regular basis (ie. yearly, biennially, every five years...). In most cases, these indicators have already been developed by various groups, commissions, or agencies. The goal of this project is to gather the indicators that will be most useful basin-wide and understandable to the interested public (including educators, media, and decision-makers) while remaining scientifically valid.

Project Objectives: To present indicators that represent portions of the Great Lakes ecosystem but show the state of and trends (improving, deteriorating or neutral trends) of a larger ecosystem component so that, used all together, the health of the system can be assessed.

Criteria: The following criteria have been adapted from a recent EPA document, *Process for Selecting Environmental Indicators and Supporting Data*, modified slightly to better fit this project. The three main criteria discussed at length with the SOLEC 98 Steering Committee and the Indicator Group are: 1) are the indicators ***necessary*** to determine the overall health of the Great Lakes; 2) are the indicators ***sufficient*** to determine the overall health of the Great Lakes; and 3) are the indicators ***feasible*** (economically and in terms of human resources) to use in determining the health of the Great Lakes ecosystem? Additional criteria useful for selecting SOLEC indicators are also included.

Criterion	Explanation	Rating*
Validity		
Relevance	Does the indicator present information relevant to Great Lakes ecosystem integrity?	
Appropriate Scale	Does the indicator respond to changes on appropriate geographic (ie. lakewide, basin-wide) and temporal (ie. monthly or yearly) scales for SOLEC reporting?	
Accurate	Does the indicator accurately reflect the ecosystem component it is intended to represent?	
Sensitive	Is the indicator appropriately sensitive, i.e., are changes in the indicator highly correlated with changing trends in the information it is selected to represent?	
Discriminating	Can the indicator distinguish natural variability from human-induced changes?	
Understandability		
Understandable	Is the indicator appropriate for decision-makers and the general public? Is the level of information from the indicator appropriate for environmental managers to use in decision making?	
Simplicity	Is the indicator simple and direct?	

Criterion	Explanation	Rating*
Presentation	Can the indicator be presented in a format tailored to environmental managers?	
Documented	Is the methodology used to create the indicator well-documented and understandable so that it can be easily communicated and reproduced?	
[illegible]		
Interpretable	Is there a reference condition or benchmark for the indicator against which current status and trends can be compared?	
Trend Evaluation	Will data that have been collected over a sufficient period of time allow analysis of trends?	
[illegible]		
Richness	Does the indicator represent multiple ecosystem components or stressors?	
Broad Application	Is the indicator broadly applicable to many geographic areas?	
[illegible]		
Currently existing	Are adequate data available for immediate indicator use?	
Easily Available	Are data easily available? Can they be retrieved with a minimum of fuss?	
Long term record	Do data currently exist to allow for analysis of environmental trends?	
[illegible]		
Timely	Are changes in the environment reflected quickly by the indicator?	
Anticipatory	Does the indicator provide early warning of changes?	
[illegible]		
Ease of Quantification	Does the indicator reflect a feature of the environment that can be quantified simply, using standard methodologies with a known degree of accuracy and precision?	
Data collection	Can data supporting the indicator be obtained with reasonable cost and effort by some Great Lakes organization?	
Calculation and Interpretation	Can calculations and interpretations for the indicator be obtained with reasonable cost and effort?	

* The rating system used during the development of the Indicator List presented at SOLEC 98 (Version 2) was left to the discretion of the Core Groups: some opted to use a simple Yes or No system while a few used a more complex number rating system.

Criteria for the whole SOLEC Indicator List:

Are each of these indicators in combination **necessary** to assess the overall health of the Great Lakes ecosystem?

Are these indicators in combination **sufficient** to assess the overall health of the Great Lakes ecosystem?

Appendix 5 — The SOLEC Indicator Database

This appendix provides details of the fields and features of the SOLEC Indicator Database (described briefly in Section 3.7 of this report).

Database Features - Things it can do

The database was designed primarily to assist the SOLEC Indicator Group organize and sort the hundreds of indicators that were identified for the Great Lakes. Fields were incorporated to provide descriptive information about each indicator, e.g., its title, the specific measurement to be taken, the ecosystem objectives that it supports, the purpose for the indicator, its desired endpoint or some other reference value, its features and limitations, how it will be displayed graphically, information to help interpret the indicator, and any additional comments. Taken together, this information provides a basis for a review of the proposed indicator against the SOLEC criteria, and a rationale for indicator selection for the SOLEC list.

Additional fields in the database were designed to hold information useful for sorting the indicators and tracking their progress through the process of SOLEC indicator selection. Included is information about the original source for each indicator (by Great Lakes program and/or reference document), indicator type, applicability to SOLEC categories, applicability to a number of alternative groupings (e.g., IJC Desired Outcomes), data availability, and whether the indicator had been modified or selected for the SOLEC list. Further details of the database fields and the information they contain are presented in the Database Fields section below.

All of the information about a selected indicator can be viewed on screen. A user can therefore select any given indicator, identify to which groupings it is applicable, obtain full descriptive information, and determine if a current data source has been identified.

To make the database useful to others besides the Indicator Group, additional capabilities have been added. A user has the ability to filter the indicators by a number of criteria. By entering a key word or phrase, a user can search through the Title, Measure and Purpose fields for indicators that contain the key word. For example, a search on "contamin" in these three fields will return a list of all the proposed indicators that mention contaminant, contaminants, contaminate, contaminates, contamination, contaminating, etc. All the indicators in the database can be included, or the search can be restricted to only those proposed as SOLEC indicators.

Sorting is also possible for the proposed SOLEC indicators according to a number of alternative groupings, in addition to the SOLEC categories. Groupings have been provided for indicator type (state, pressure or human activity (response)), environmental compartments, Great Lakes issues, GLWQA Annexes, GLWQA Beneficial Use Impairments, IJC Desired Outcomes, and Great Lakes Fishery Commission Objectives.

Reporting capabilities are also being incorporated into the database and will be available with the online version. Users will be able to select pre-formatted reports based on results of the sorting criteria, from simple lists of indicator titles to full page indicator descriptions. User-specified reports for selected fields in the database will also be possible.

Database Fields - Information stored about each indicator

The following are descriptions of the fields and the information they contain in the SOLEC indicator database. Not all information is available for all the indicators in the database. The most complete entries are provided for the proposed SOLEC indicators.

The Indicator "Description" Information

Name of Indicator. What is a brief, descriptive title for the indicator? Example: *Contaminants in Top Predator Fish*

Measure. What is really being measured? Example: *PCB congeners in 6 year old lake trout*

Ecosystem Objective. What environmental goals or objectives does the indicator address or support? Example: *Lake Superior LaMP Human Health Objective, "Fish and wildlife . . . should be safe to eat"*

Purpose of the Indicator. What is the larger category of interest? An indicator is a surrogate for something more consequential than the indicator, per se. Does the indicator provide information about the environment or human health, about a stressor (contaminants, habitat, exotic species, etc.), about sources of the stressors (industrial discharge, wetland diking, etc.), or about human activities (or responses such as laws, volunteer programs, etc.). Example: *A direct measure of the level of organic contaminants in the food chain and an indirect measure of potential harm to human health through consumption of contaminated fish.*

Endpoint. (Or range, outcome or other reference value) What is the frame of reference to interpret the indicator? Example: *FDA Action Limit = 2.0 ug/g PCB in fish tissue.*

Features of the Indicator. As applicable, describe space and/or time scales represented by the indicator, anticipated variability, linkages with other indicators, and/or other information to help determine or document the viability of this indicator to be included on the SOLEC list. Example: *Measurement of the concentration of PCBs in whole lake trout has been part of an annual program for over 20 years. To reduce variability in the analytical results and to increase the ability to track trends in the levels of contaminants over time, fish from the same age/size are collected each year from designated locations in each lake, and they are composited for analysis . . . .*

Illustration. What will be displayed graphically? How will the display incorporate the desired endpoint or reference value? Example: *For each lake, a graph will be displayed showing the annual mean concentration and 95% confidence intervals of total PCBs in lake trout composites. The data series from 1972 to the present will be included. Reference concentrations will be marked on the figure for comparison to the measured values.*

Limitations of the Indicator. How costly are the data to collect at the recommended frequency? What issues may compromise the utility of the indicator? How closely linked is the indicator to the broader issue being assessed? Example: *This is a relatively costly indicator that requires much coordination and collaboration between federal, state and provincial agencies. The indicator, however, is very closely linked to the overall abundance of mobile PCBs in the Great Lakes ecosystem. The indicator is an integrator of the level of PCBs in the* *food web over large areas of each lake over several years, therefore it cannot be effectively associated with specific sources.*

Indicator Interpretation. Is other information needed to place this indicator in context? On what basis can the subjective tags of "good" and "poor" be applied to the state of the environment or to progress toward the ecosystem objective being supported by the indicator? Example: *Variations in feeding habits or food web structures could affect annual results and complicate interpretations of long-term trends. Measurements of PCBs (particulate and dissolved) in the water column would help distinguish food web influences from changes in the environmental concentrations of PCBs. A scale from, say 50 ppm (worse than found in 1972) to 0.05 ppm (the proposed health protection value, even though it is for fillets and not whole fish) could be used to apply subjective assessments to the degree to which the ecosystem is free from PCBs: 50 ppm = totally unacceptable, 5 ppm = poor, 0.5 ppm = fair and 0.05 ppm = good.*

Comments. Provide any other information that would assist the process of indicator selection or the application of the indicator. Is a particular methodology required? Are special calculations needed to derive or interpret the indicator? Is additional work needed to define the indicator? Is the indicator feasible? Example: *To maintain compatibility with the historic, long-term data, established protocols for fish collection, sample preparation and analysis must be followed. This indicator has been in use in the Great Lakes basin for over 20 years. It is directly related to Great Lakes objectives, widely accepted, easily understood, and the supporting data are of high quality.*

The Indicator "Sorting" Information

Indicator Name. This field is copied from the "description" section above.

Measure. This field is copied from the "description" section above.

Reference Document. What document did the indicator come from? Major sources of proposed Great Lakes indicators included the Lakewide Management Plans, IJC, Great Lakes Fishery Commission, and previous SOLEC background documents.

Indicator Type. For which element of the State-Pressure-Human Activities (Response) framework does the indicator provide information?

Applicable SOLEC Indicator Category. Previous SOLEC presentations and reports were organized around a few major ecosystem components and human interactions. To be consistent with, and extend these foundations, the indicators can be grouped accordingly. The categories include: Open Waters, Nearshore Waters, Coastal Wetlands, Nearshore Terrestrial, Land Use, Human Health, Societal and Unbounded.

Applicable to other programs or groups. The SOLEC Indicator Group has made an initial judgement concerning the applicability of each indicator to other programs or useful groupings. Current groupings have been provided for environmental compartments (e.g., air, water, land, sediments, biota, fish, humans), Great Lakes issues (e.g., contaminants and pathogens, nutrients, exotics, habitat, climate change, stewardship), GLWQA Annexes, GLWQA Beneficial Use Impairments, IJC Desired Outcomes, and Great Lakes Fishery Commission Fish Community Objectives.

Status as SOLEC Indicator? The database has been useful to help organize and sort indicators, but not every indicator will be nominated to the SOLEC List. Therefore, a field containing the status of each indicator was included in the database. " *Under Consideration* " applies to those indicators under consideration for the SOLEC List. " *Selected* " applies to those which are included in the SOLEC list. " *Not Selected* " applies to those not proposed for the SOLEC list, even though they may be useful in another context. " *Concept Retained* " applies to those which contain one or more features that were combined, merged, or altered and that exist in another, related indicator (with the new indicator number in brackets—i.e. Concept Retained (7008) means that a feature of this particular indicator exists in indicator number 7008).

Data Availability. Recent data that directly support the indicator would greatly improve an illustration of the indicator and would provide a means to immediately report on the ecosystem component being measured. Three aspects to indicator data are retained in the database: *Data Availability* (Yes, No, Unknown), *Data Quality* (Excellent, Good, Fair, Poor, Unknown), and *Data Source and Comments* (Where are the data? Is a time series available? What other information is available about the data?).

Appendix 6: Acronyms and Commonly Used Abbreviations

AoC	Area of Concern
BIA	Biodiversity Investment Area
BOD	Biological Oxygen Demand
BUI	Beneficial Use Impairment
CAPMoN	Canadian Air and Precipitation Monitoring Network
Cd	cadmium
Cs	cesium
CO	carbon monoxide
CWS	Canadian Wildlife Service
DELT	Deformities, Eroded fins, Lesions and Tumors
DDE	metabolite of DDT
DDT	dichlorodiphenyltrichloroethane
DFO	Department of Fisheries and Oceans Canada
F2	2nd generation: offspring from successful mating
FCGO	Fish Community Goals and Objectives
FERC	Federal Energy Regulatory Commission (U.S.)
FFG	Functional Feeding Groups
FTE	Full Time Equivalent (with respect to number of employees)
GIS	Geographic Information System
GLFC	Great Lakes Fishery Commission
GLWQA	Great Lakes Water Quality Agreement, as amended by Protocol signed November 18, 1987
ha	hectare; 10,000 square metres; 2.47 acres
Hg	mercury
IADN	International Atmospheric Deposition Network
IBI	Index of Biotic Integrity
IJC	International Joint Commission
IUCN	International Union for the Conservation of Nature
LaMP	Lakewide Management Plan
LRTAP	Long-Range Transport of Atmospheric Pollutants
MAB	Man and the Biosphere. Initiated by UNESCO to address problems relating to conservation of resources, resources systems, and human settlement development.
MMP	Marsh Monitoring Program
NDDN	National Dry Deposition Network (U.S. Park Service)
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NO_x	Nitrogen Oxides (nitrous, nitric)

O_3	Ozone
Ohio EPA	Ohio Environmental Protection Agency
OMOE	Ontario Ministry of the Environment
PAH	polynuclear aromatic hydrocarbons
Pb	lead
PBT	Persistant, Bioaccumulative, and Toxic chemicals
PCB	polychlorinated biphenyls
PCDD	polychlorinated dibenzo dioxins
PCDF	polychlorinated dibenzo furans
PTS	Persistent Toxic Substance
RAMSAR	The Convention on Wetlands, signed in Ramsar, Iran in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
RAP	Remedial Action Plan
SO_2	sulfur dioxide
SOLEC	State of the Lakes Ecosystem Conference
SP	Suspended Particulates
spp.	species
Sr	strontium
TRS	Total Reduced Sulfur
UNESCO	United Nations Educational, Scientific and Cultural Organization
USEPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service

Appendix 7 — Documents

The following table lists most of the documents and reports used by the Core Groups to extract indicators and other information. Please go to the end of the table for a list of the acronyms used here. (*Note that the document reference number has been revised since Version 3*).

Ref. No.	Document Sponsor	Document	Core Group(s)						
			OW	NW	CW	NT	HH	LU	S
1	GLFC	Busiahn, T.R. (ed) 1990. *Fish-Community Objectives for Lake Superior.* Great Lakes Fishery Commission Special Publication 90-1. 23 pp.	X	X					
2	GLFC	Eshenroder, R.L. et al. 1995. *Fish-Community Objectives for Lake Michigan.* Great Lakes Fishery Commission Special Publication 95-3. 56 pp.	X	X					
3	GLFC	Kerr, S. J. and G.C. Le Tendre. 1991. *The State of the Lake Ontario Fish Community in 1989.* Great Lakes Fishery Commission Special Publication 91-3. 38 pp.		X					
4	GLFC	Lake Erie Committee. 1997. *Lake Erie: Fish Community Goals and Objectives.* 34 pp.		X					
5	GLFC	DesJardine, R.L. et al. 1995. *Fish-community objectives for Lake Huron.* Great Lakes Fishery Commission Special Publication 95-1. 38 pp.		X					
6	GLFC	Great Lake Fishery Commission. 1995. *Habitat Advisory Board Meeting # 95-2, Minutes with Attachments.* 410 pp.		X					
7	Michigan LaMP	Esparza et al. 1996. *Lake Michigan Indicators: Degradation of Wildlife Population/Bird or Animal Deformities - Population Viability (draft).* 6 pp.			X	X			
8	Michigan LaMP	Esparza et al. 1996. *Matrix for Aquatics/Habitat Indicators for Lake Michigan.* 6 pp.	X	X	X				
9	Ontario LaMP	Lake Ontario Pelagic Community Health Indicators Committee (LOPCHIC). 1993. *Lake Ontario: An Ecosystem in Transition.* 65 pp.	X	X					
10	Ontario LaMP	Lake Ontario Ecosystem Objectives Working Group. 1992. *Progress Report of the Ecosystem Objectives Working Group on Ecosystem Objectives and Environmental Indicators for Lake Ontario.* 61 pp.	X	X					X
11	Ontario LaMP	Lake Ontario Ecosystem Objectives Working Group. 1993. *Indicators of Progress Toward Lake Ontario Ecosystem Objectives.* 6 pp.				X			
12	Superior LaMP	Lake Superior Work Group and Lake Superior Binational Forum. 1996. *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior.*				X	X	X	X
13	SOLEC	De Vault, D. et al. 1995. *Toxic Contaminants in the Great Lakes.* Background paper. State of the Lakes Ecosystem Conference 1994. 37 pp.	X						
14	SOLEC	Manno, J. et al. 1995. *Effects of Great Lakes Basin Contaminants on Human Health.* Background paper. State of the Lakes Ecosystem Conference 1994. 83 pp.					X		
15	SOLEC	Koonce, J.F. 1995. *Aquatic Community Health of the Great Lakes.* Background paper. State of the Lakes Ecosystem Conference 1994. 37 pp.	X						

Ref. No.	Document Sponsor	Document	Core Group(s)						
			OW	NW	CW	NT	HH	LU	S
16	SOLEC	Dodge, D. and R. Kavetsky. 1995. *Aquatic Habitat and Wetlands of the Great Lakes*. Background paper. State of the Lakes Ecosystem Conference 1994. 70 pp.	X		X				
17	SOLEC	Allardice, D.R. and S. Thorp. 1995. *A Changing Great Lakes Economy: Economic and Environmental Linkages*. Background paper. State of the Lakes Ecosystem Conference 1994. 45 pp.						X	
18	SOLEC	Neilson, M. et al. 1995. *Nutrients: Trends and System Response*. Background paper. State of the Lakes Ecosystem Conference 1994. 20 pp.	X	X					
19	SOLEC	United States/Canada. 1995. *State of the Great Lakes 1995*. 56 pp.		X	X				
20	SOLEC	Reid, R. and K. Holland. 1997. *The Land by the Lakes: Nearshore Terrestrial Ecosystems*. Background paper. State of the Lakes Ecosystem Conference 1996. 142 pp.				X			
21	SOLEC	Leger, W. and R. Greenwood. 1997. *Information and Information Management*. Background paper. State of the Lakes Ecosystem Conference 1996. 96 pp.			X				
22	SOLEC	Maynard, L. and D. Wilcox. 1997. *Coastal Wetlands*. Background paper. State of the Lakes Ecosystem Conference 1996.			X				
23	SOLEC	Edsall, T.A. and M.N. Charlton. 1997. *Nearshore Waters of the Great Lakes*. Background paper. State of the Lakes Ecosystem Conference 1996. 152 pp.		X					
24	SOLEC	Thorp, S., R. Rivers, and V. Pebbles. 1997. *Impacts of Changing Land Use*. Background paper. State of the Lakes Ecosystem Conference 1996. 118 pp.			X			X	
25	SOLEC	United States/Canada. 1997. *State of the Great Lakes 1997*. 76 pp.		X	X	X			
26	SOLEC	Fuller, K. and H. Shear. 1996. *Integration Paper*. State of the Lakes Ecosystem Conference 1996. 65 pp.					X		
27	IJC	Ryder, R.A. and C.J. Edwards. 1985. A Conceptual Approach for the Application of Biological Indicators of Ecosystem Quality in the Great Lakes Basin. 167 pp.		X		X			
28	IJC	IJC Ecosystems Objectives Committee. 1990. *Final Report of the Ecosystem Objectives Committee*. 53 pp.		X					
29	IJC	Edwards, C.J. and R.A. Ryder (eds). 1990. Biological Surrogates of Mesotrophic Ecosystem Health in the Laurentian Great Lakes. 69 pp.	X	X					
30	IJC	Seidl, P.J. (ed). 1993. *Toward a State of the Great Lakes Basin Ecosystem Report*. State of the Great Lakes Basin Ecosystem Task Force. 162 pp.	X						
31	IJC	IJC. 1996. *Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement*. 82 pp.		X	X	X			
32	IJC	Fox (ed). 1994. *Bioindicators as a Measure of Success for Virtual Elimination of Persistent Toxic Substances*. 37 pp.		X	X	X			
33	EC	Campbell, M., D. Spear, and V. MacLaren. 1996. *Measuring Up: A Resource Guide for Municipal State of the Environment Reporting*. 70 pp.	X						
34	EC	Environment Canada Indicators Task Force. 1991. *A Report on Canada's Progress Towards a National Set of Environmental Indicators*. SOE Report 91-1. 98 pp.		X					
35	EC/CMHC/ ICURR	MacLaren. V.W. 1996. *Developing Indicators of Urban Sustainability: A focus on the Canadian Experience*. 147 pp.						X	

Ref. No.	Document Sponsor	Document	Core Group(s)						
			OW	NW	CW	NT	HH	LU	S
36	EC/GLFC/ USEPA	Hartig, J. 1993. *A Survey of Fish-community and Habitat Goals/Objectives/Targets and Status in Great Lakes Areas of Concern*. 95 pp.		X					
37	EC/NNC	Snell, E. 1997. *Great Lakes Biomonitoring Project: Initial Development of a Framework for Monitoring Priority Coastal Marsh Health and Integrity*. 70 pp.			X	X			
38	EC	Environment Canada et al. 1997. *A Compendium of Ecosystem Health Goals, Objectives and Indicators* (Prototype). 132 pp.			X	X			X
39	USEPA	USEPA. 1998. *Communicating Information on the Condition of Terrestrial Ecosystems. A Focused Investigation of Indicators of Terrestrial Ecosyste[illegible]alth* (initial draft).				X			
40	USEPA	Fabrizio, M.C., C.P. Ferreri and M.J. Hansen. 1995. *Prey Fish Communities as Indicators of Ecosystem Health in Lake Michigan*. 130 pp.	X						
41	USEPA	USEPA. 1990. *Environmental Monitoring and Assessment Program (EMAP) Ecological Indicators*. ~425 pp.		X	X				
42	USEPA	Keough, J.R. and J. Griffin. 1994. *Technical Workshop on Environmental Monitoring and Assessment Program (EMAP) Indicators for Great Lakes Coastal Wetlands, Summary Report*.			X				
43	OMNR/ NYSDEC	OMNR/NYSDEC. 1994. *Ecosystem Watch: Status of the Lake Ontario Ecosystem*. 8 pp.	X						
44	CCFM	Canadian Council of Forest Ministers. 1997. *Criteria and Indicators of Sustainable Forest Management in Canada, Technical Report*. 137 pp.				X		X	
45	State of Minnesota	State of Minnesota. 1997. *Environmental Indicators Initiative* (Draft).				X			
46	GLC	Great Lakes Commission. 1996. *An Agricultural Profile of the Great Lakes Basin: Characteristics and Trends in Production, Land-use and Environmental Impacts*.				X			
47	OECD	OECD. 1998. *OECD Environmental Indicators for Sustainable Development* (Draft in Progress). 117 pp.				X			
48	NCASI	LTI-Limno Tech, Inc. 1993. *Great Lakes Environmental Assessment*. 270 pp.				X			
49	Health Canada	Health Canada, Great Lakes Health Effects Program.					X		
50	Health Canada	Riedel, D., N. Tremblay and E. Tompkins (eds). 1997. *State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin*. Great Lakes Health Effects Program. 482 pp.					X		
51	Health Canada	Health Canada. 1998. *Persistent Environmental Contaminants and the Great Lakes Basin Population: An Exposure Assessment*. Great Lakes Health Effects Program.					X		
52	Health Canada	Health Canada. 1996. "Outdoor Air and Your Health - A Summary of Research Related to Health Effects of Outdoor Air Pollution in the Great Lakes Basin". Great Lakes Health Effects Program.					X		
53	Health Canada	Health Canada. 1995. "Great Lakes Water and Your Health - A Summary of 'Great Lakes Basin Cancer Risk Assessment: A Case-control Study of Cancers of the Bladder, Colon and Rectum". Great Lakes Health Effects Program.					X		
54	Health Canada	Health Canada. 1992. *Atlas I - Birth Defects Atlas of Ontario: 1978-1988*. Great Lakes Health Effects Program.					X		

Ref. No.	Document Sponsor	Document	Core Group(s)						
			OW	NW	CW	NT	HH	LU	S
55	Health Canada	Health Canada. 1992. *Atlas II - Cancer Incidence in the Great Lakes Region, Ontario: 1984-1988.* Great Lakes Health Effects Program.					X		
56	OCTRF						X		
57	OMH						X		
58	GLPF/ USATSDR/ NYGLRC	Myers, S. et al. 1996. *Report on Incorporating Human Health Considerations into RAPs*. 62 pp.					X		
59	NYSDEC	Kagey and Stark. 1992. *Indicators of Human Reproductive Health within the Great Lakes Drainage Basin Ecosystem.* 59 pp.					X		
60		Craan, A.G. and D.A. Haines. 1988 (submitted). "Twenty-five years of surveillance for contaminants in human breast milk". *Arch. Environ. Contm. Toxicol.*					X		
61		Wang, S.T. et al. "Decline in blood lead in Ontario children correlated to decreasing consumption of leaded gasoline, 1983-1992". *Clinical Chemistry.* Vol 43, 1251-1252 pp.					X		
62	U of T	MacLaren. V.W. 1996. "Urban Sustainability Reporting". *Journal of the American Planning Association.* Vol. 62, No. 2., 184-201 pp.						X	
63	U of T	D. Mackay. 1998. Personal Communication. Trent University, Peterborough, Ontario.	X						
64		Wackernagel, M. and W. Rees. 1996. *Our Ecological Footprint.* New Society Publishers, British Columbia, Canada.						X	
65	GLC	1994. *Ecosystem Charter for the Great Lakes-St. Lawrence Basin.*							X
66	OMMAH	OMMAH. 1998. *Performance Indicators for Planning (Pilot Studies). A draft set of planning indicators for pilot study purposes in sample communities in Ontario.*						X	
67		LURA Group. 1995. *Measuring Urban Sustainability: Canadian Indicators Workshop.*							
68	USEPA	U.S. Environmental Protection Agency. 1997. *Process for Selecting Environmental Indicators and Supporting Data.* Data Quality Action Team, EPA Contract No. 68-W4-0031, D04; Washington, D.C., 78pp.							

Core Groups

OW	Open Waters
NW	Nearshore Waters
CW	Coastal Wetlands
NT	Nearshore Terrestrial
HH	Human Health
LU	Socio-economics/Land Use
S	Societal

Acronyms

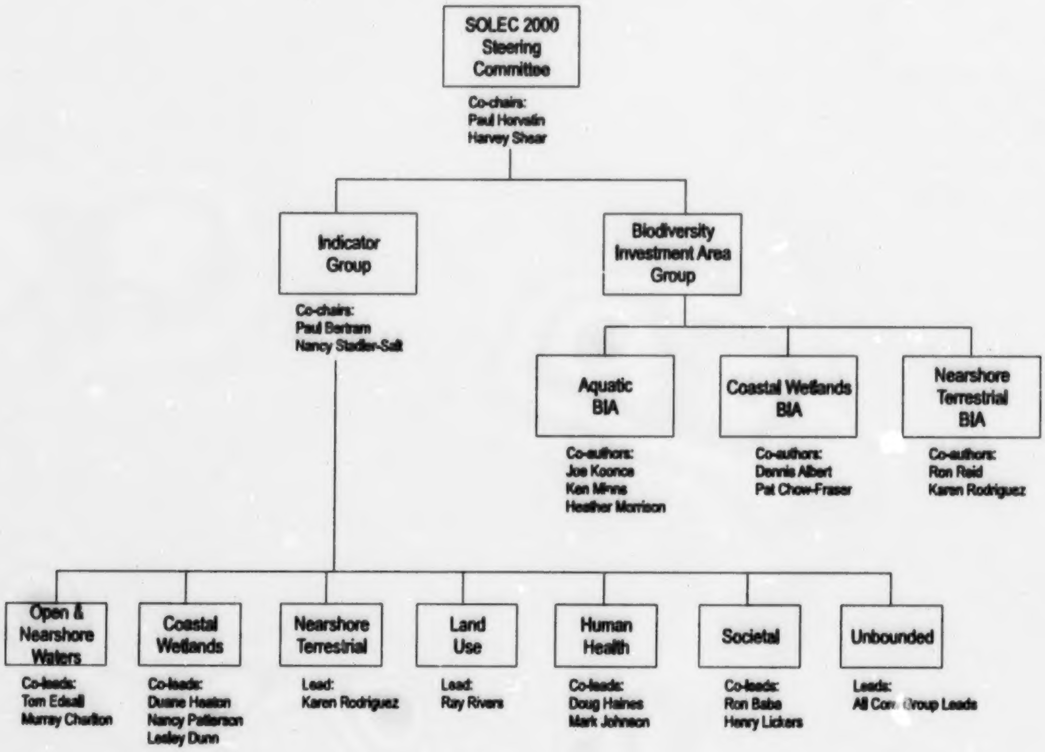
CCFM	Canadian Council of Forest Ministers
CMHC	Canadian Mortgage and Housing Commission
EC	Environment Canada
GLC	Great Lakes Commission
GLFC	Great Lakes Fishery Commission

GLPF	Great Lakes Protection Fund
ICURR	Intergovernmental Committee on Urban and Rural Research
IJC	International Joint Commission
NCASI	The National Council of the Paper Industry for Air and Stream Improvement
NNC	The Nature Conservancy of Canada
NYGLRC	New York Great Lakes Research Consortium
NYSDEC	New York State Department of Environmental Conservation
OCTRF	Ontario Cancer Treatment Research Foundation
OECD	Organisation for Economic Co-operation and Development
OMH	Ontario Ministry of Health
OMMAH	Ontario Ministry of Municipal Affairs and Housing
OMNR	Ontario Ministry of Natural Resources
SOLEC	State of the Great Lakes Ecosystem Conference
USATSDR	United States Agency for Toxic Substances and Disease Registry
USEPA	United States Environmental Protection Agency
U of T	University of Toronto

Appendix 8 — SOLEC 2000 Organizational Structure (simplified)

The chart below depicts a simplified SOLEC 2000 organizational structure. The members of the Indicator Group, the six Core Groups, and the Steering Committee as of October 1998 are listed in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 3*. These groups are dynamic in nature, therefore membership changes have occurred since SOLEC 98.

This report does not discuss the Biodiversity Investment Area group or the papers produced by this group—for more information on these papers please visit one of the SOLEC websites:
http://www.cciw.ca/solec/
http://www.epa.gov/glnpo/solec/


SOLEC 2000 Steering Committee
Co-chairs:
Paul Horvatin
Harvey Shear
Indicator Group
Co-chairs:
Paul Bertram
Nancy Stadler-Salt
Biodiversity Investment Area Group
Aquatic BIA
Co-authors:
Joe Koonce
Ken Minns
Heather Morrison
Coastal Wetlands BIA
Co-authors:
Dennis Albert
Pat Chow-Fraser
Nearshore Terrestrial BIA
Co-authors:
Ron Reid
Karen Rodriguez
Open & Nearshore Waters
Co-leads:
Tom Edsall
Murray Charlton
Coastal Wetlands
Co-leads:
Duane Heaton
Nancy Patterson
Lesley Dunn
Nearshore Terrestrial
Lead:
Karen Rodriguez
Land Use
Lead:
Ray Rivers
Human Health
Co-leads:
Doug Haines
Mark Johnson
Societal
Co-leads:
Ron Baba
Henry Lickers
Unbounded
Leads:
All Core Group Leads

Appendix 9 — Comments on Indicators (Version 3) with Responses

A9.1 Comments with Responses from SOLEC Indicators Group

The following is a compilation of comments received on both the report *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 3* and on specific indicators within the report. These comments have been grouped into one of the following categories: General Comments; Open and Nearshore Waters; Coastal Wetlands; Nearshore Terrestrial; Land Use; Human Health; Societal; and Unbounded. Responses have been prepared by the SOLEC Indicator Group, they follow each comment and are in italics.

General

1. Although the document title claims that the indicators were derived for the Great Lakes basin ecosystem, a disproportionate number of the indicators describe the state of the lake waters and their shorelines. Perhaps a more representative title would mention Great Lakes Aquatic Ecosystem Health rather than the basin. A total of 46 indicators have been developed to monitor and describe the state of open waters, nearshore waters, coastal wetlands and nearshore terrestrial areas.
   We recognize that there is much more work needed on the terrestrial portion of the basin (and will happen in the future), but as it now stands, we are using indicators that we hope are a catchment of what is happening farther up in the land basin (i.e. Monitoring at the shoreline). The report title will remain as is.

2. The importance of establishing and consistently following protocols for monitoring and for inclusion of data in indicators can never be over-stated.
   We agree about this - it will be future work as the process evolves.

3. Further development work could also consider an indicator or two that goes beyond single species and looks into the biodiversity characteristics of various parts of the basin or aquatic ecosystem.
   We agree on this as well - but this is very complex. We currently have indicators that use "indices of biotic integrity", but they need further development work before we can monitor for them fully.

4. Some thought could be given to the development of specialized "early warning" indicators that are able to signal changes in the ecosystem before they become permanent. For example, it would be useful to have indicators that could detect the emergence of exotic species or species range extensions or could detect the environmental changes that precede these shifts.
   The state indicators will tell us about changes in the state of the system, but perhaps the best "early warning" will be with zooplankton which are quick to respond to changes in the system. Early warnings may emerge when trends come out of enough data.

5. The language in Version 3, has been edited to the point of making the document of little use to anyone. It appears that the indicator description language has compromised the scientific credibility of nearly every indicator. For example:
   Contaminants in Snapping Turtle Eggs (Indicator #4506)

> *This indicator will measure the accumulation of organochlorine chemicals and mercury in Snapping Turtle eggs and indirectly measure the concentrations, as well as identify the source, of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.*

This is one of the best examples of the problems with the new Version 3 language. Of course, any measurement of organochlorine chemicals and mercury will be direct measurements, certainly not **indirect measurements of concentrations**. And certainly, measurement of turtle egg concentrations in and of themselves cannot **identify the source**. Much additional investigation is needed to pinpoint sources.

We agree that the short blurbs (taken from the Purpose statement in the descriptor information) for each indicator needed work. They have been revised for the Version 4 indicator descriptions.

6. Section 2.5: Stress that list of indicators are not static - they will evolve with our understanding of the system, and as warranted by "surprises".

   We strongly agree with this, and have also stressed this point in the 1999 State of the Great Lakes report.

7. In general, the indicators are quite detailed and numerous. It may be difficult for the lay-person or general policy-maker to interpret all this information. Depending on who the intended audience is, the indicators will need to be packaged and interpreted in a way that is easy to understand and educates the reader. Consideration could be given to combining the indicators into an index within each of the seven indicator groups which could help to summarize the situation and provide a bit of context for the general reader. This comment is particularly relevant with respect to many of the biological measures listed under Nearshore and Open Waters, Coastal Wetlands and Nearshore Terrestrial indicator groups. Two alternatives to developing an index would be to:
   i. Choose a "key" or "reference" indicator that summarizes the "state" or "pressure" under each of the seven indicator groups and organize the other indicators as supporting or "second tier" indicators which provide more detailed information. For example, the aquatic habitat indicator would be a good summary indicator of the Nearshore and Open Waters indicator group since both the health of fish and other wildlife populations are dependent on a good supply of quality habitat. It could be considered to be a "key" or "reference", state indicator.
   ii. A second option is organize the presentation of the indicators so that they give a visual impression of all the trends at once (e.g., multiple mini-graphs) and include an informative, easy-to-understand summary of the situation.

   We agree that summarizing the information into some type of indices will be useful and we will work towards this, however we would like to stress that the whole suite of indicators will always be very important to give detailed information to middle managers and allow them to make sound management decisions.

8. Overall, there are quite a few scientific and technical terms used in some of the indicators. In the absence of a glossary (Appendix 6: Definitions and Acronyms does not clarify such terms), some of these should be explained within the text for the particular indicators. For example, for Indicator #72, Fish Entrainment, the precise sense of "fish entrainment" is not at all clear, and dictionary definitions did not help to clarify it. In the same indicator, what are "sentinel" species? For Indicator #101, Deformities, Erosions, Lesions and Tumours in Nearshore Fish, what is the sense of "erosion" with respect to fish? The sense of it

actually becomes more apparent in Indicator #4503, which uses the term "eroded fins". Brownfield Redevelopment (#7006) The term "brownfield" could use some clarification.

We agree that there are many technical terms throughout the indicator descriptions, but this is, after all, a technical document. Although we have tried to use clear, yet concise language, the use of a technical term can save many words of alternate explanation. Terms like "sentinel" and "brownfield" have become an established part of our lingo to talk about Great Lakes issues.

9. There are no direct indicators presented on the condition of groundwater, streams or rivers in the Great Lakes basin, although this is covered indirectly under other indicators. It may be worth considering having representative indicators (under the Land Use indicator group) that provide a picture of the state of the other water bodies that flow into the lakes.

   We agree that this isn't yet included in the suite of indicators, we still have some work to do...

10. Considering the current high profile of endocrine disruption and endocrine disrupting substances, it is rather surprising that there are no indicators specifically focusing on this issue. In Appendix 1, endocrine is only mentioned once, and that being a comment with respect to Indicator #4179, Pattern and Trends in Disease Incidence: "this indicator could be expanded in the future to include biomarkers of pre-disease conditions, ***endocrine disruption***, and low birth weight."

    Endocrine disruption is an issue that is driving policy. However, endocrine disruption is a mechanism of action potentially affecting a large number of subtle health endpoints, rather than an endpoint in itself. The research is still in the developmental stage and at this time, it is not clear what could be included in such an indicator. Indicators 4177, 4083, and 4088 all include measurements of persistent and bioaccumulative toxic substances, some of which are suspected endocrine disruptors. This is a wildlife issue as well. In the SOLEC suite we do look at the effects of ED (i.e. contaminants in turtle eggs, patterns and trends in disease incidence...).

11. I am still perplexed as to how they plan to implement these. For example, preyfish populations (#17): the "measure" includes abundance, diversity, age and size of preyfish species. The "endpoint" only uses abundances, but these are yet undefined. The "features" and "illustrations" infer trends in multiple prey species will be evaluated to produce an index of potential predator biomass that can be produced from a prey complex. Wow, that task alone seems to define a career, and even if it were evaluated it would only represent a static condition that is likely lake specific and must be viewed independent of the other ecosystem linkages. i.e. if they found that 1 kg/ha of smelt can support chinook salmon in Lake Ontario (ignoring all other prey fishes) given a specific physical state (temperature and light), what happens if the temperature increases (will increase predator demand, or alter it's distribution and therefore potential overlap with prey), or smelt prey declines, or lake herring recruitment improves (alternate prey), or another predator (with it's own characteristic energetic demand, behavior and distribution) arrives in the system. In other words, 1 kg/ha of smelt may support X kg of chinook, or it may not - and I think the may nots will dominate given the ecosystem complexity.

    At this time many endpoints for the indicators are undefined and it will be a difficult process. However measurements are collected and the trends that these measurements show are a good place to start. We do have to use caution when interpreting the data.

12. I had conceptual difficulties with developing indicators and then linking them to a variety of objectives rather than vice versa. I understand the concept of multi-functional indicators, but in some cases, they aren't necessarily viewed the same way depending upon the

readers perspective.

We are servicing a number of objectives (see the table in Appendix 3). We recognize that it is not a perfect system but had to start someplace. We are aiming for parallel, collaborative processes (i.e. with the LaMP groups).

13. In some instances, the numeric value identified for a fisheries related objective was no longer relevant. In an era of rapid ecosystem change, the quantitative element of some of our biological elements may be only fleetingly relevant.

    The endpoints will need to be adjusted as the situation warrants - but we still need to collect the data regardless of the endpoint. We agree that the most current numeric targets will provide the best context in which to evaluate indicator data.

14. My other concern was attempting to develop a "state of the environment objectives" that covered off environment, quality and quantity of natural resources, and the state of human and ecological health, as a suite. What is a "success" for these elements based on the values of particular sectors may be in direct opposition to each other, hence the dilemma. For example, under some circumstances, what some may view as a sign of ecological health of the Great Lakes ecosystem may be in direct conflict with the social/economic health of the natural resource component. Without the context of goals and objectives for ecosystem health up front, it is difficult to evaluate the appropriateness of some of the indicators.

    We recognize that there will be conflicting results and it is inevitable that we will have to deal with this. Conflicts, however, point out the strengths of having a "suite" of indicators. Also, at this time we don't have a lot of social well-being indicators. See response for comment 12.

15. I think there were was an applaudable effort to find indicators that could serve a variety of purposes and offer a basin snapshot. It is a positive step to strive for measures of basin-wide health. However, in the end, an indicator can't be all things to all people, and it may have been better to focus in an ecosystem health perspective rather than attempting to find the ultimate indicator. The other alternative would be to split the "state of the environment" indicators description and interpretations into the sub-categories, so that some reflect the environmental state when viewed a particular way, some reflect resource quantity and quality, and other reflect basin health. I think that once the results are in place, interpreting the results by these categories would offer an interesting picture of the various social values at work, particularly if a social/economic component was added.

    We are not trying to develop the "ultimate" indicator. See response for comment 14.

16. Section 2.1 provides a definition of terms associated with indicators. The term "target" is defined as "specific, attainable, quantitative end point or reference values for an indicator.....". The term end point implies that we want or need to move in a specific direction - and I'm not sure this is the case for all of the indicators. For example, in the case of phosphorus loading, end point may be an appropriate term for Lake Erie where we are trying to move from high to lower P loading. However, in the case of Lake Superior, although we may have a certain level (i.e. criteria) of P loading we don't want to exceed I don't think we are currently trying to go in a higher or lower direction. I would suggest that Criteria would be a more appropriate term to use than Target and that the term end point be removed from the definition.

    We agree and recognize that the endpoint could possibly be the current conditions, but we don't want to remove the sense of an endpoint (or where we want to be). We want to show progress towards and endpoint in time and space (even if that means changing nothing).

17. In Appendix 1 the endpoint is used in the detailed descriptions for each indicator. To be consistent with the terminology which is presented in Section 2.1 replace endpoint with target, (or more preferably with criteria).
    No - see comment 16 response.

18. I wonder whether some of the indicators are doable and there are two aspects to this. First, are we currently collecting the information and if not, then do we have the resources to. Secondly, even if we have the necessary resources, do we really know how to measure some of these parameters and what the criteria (target) should be? (Or is significant investment in research required to develop the measurement tools and the criteria?) For example, are we currently measuring the quality and area of aquatic habitat in the Great Lakes Ecosystem? To measure aquatic habitat by area and by type in a quantitative way (i.e. relates to fish production or ecosystem health) is a huge job and I'm not aware that we are currently doing it. Furthermore, I would question whether we even have the tools/knowledge to measure and interpret this type of information in a way that is quantitative and defensible.
    We acknowledge and understand that there is still much more to be done (we are only just scratching the surface). The "next steps" will take a lot of resources.

19. For many of the proposed indicators there is not yet a defined "endpoint" or criteria. When will this be done? Are there gaps in our science which must be addressed first? This should probably get sorted out before data collection begins.
    We agree that endpoints have not yet been established for some indicators, but data collection can still proceed to identify trends or baseline information. Some indicators also need research to determine methodology and interpretation. Each indicator will be taken on a case by case basis.

20. An indicator measuring suspended solid/turbidity, pathogen, pesticide, and other drinking water contaminants of concern, at the mouths of tributaries should be added for tributaries that have the potential to affect water quality at drinking water intakes. Measure of stream flow and suspended sediments at the mouth of major tributaries and connecting channels has already been included in the Stream Flow, (#8142).
    We held a joint SOLEC-IJC workshop in August, 1999, to discuss this and other issues on "Drinkability". Results of that workshop are being used to better define measurements for indicator #4175 Drinking Water Quality.

21. With regard to #111(phosphorus), #4860 (nitrates), #104 (benthic diversity and abundance) and indicators related to deformities/contaminant effects on fish populations, additional information for assessing the state of the Great Lakes environment can be obtained from the data submitted to Environment Canada for the regulated Cycle 2 Environmental Effects Monitoring studies conducted under the Federal Pulp and Paper Effluent Regulations by the pulp and paper mills. In Ontario, there are seven mills that discharge effluent to Lake Superior so data would be available from seven EEM studies on April 1, 2000.
    Thank you for the data source.

22. Most of the indicators in the various categories have some scientific foundation in that a direct or indirect relationship can be ascribed over time between the indicator and changes in the overall quality of the Great Lakes environment. However, this is not the case with the proposed Societal Indicators. Most of the listed parameters will be subject to differing interpretations as to what impact a change in any one will have on the Great Lakes

environment. This also applies to some of the Land Use Indicators, such as transportation efficiency, green planning process, and energy consumption. Two separate documents, one dealing with environmental and one dealing with societal factors, or at least a much clearer differentiation between the two in a single document, would be more useful.

One of the overarching philosophies of SOLEC is the integration of all parts of the ecosystem (including societal and natural resource aspects). We think it would be a mistake to separate these components.

23. The issue of comparability will have to be addressed, i.e., how will data collected by various agencies using different methods be compared?

    This comment points out the necessity for SOLEC to get at issues such as this. QA/QC will be a challenge.

24. Data for many of the indicators are not currently collected on a systematic, widespread basis. How will entities involved in monitoring be encouraged to collect data in support of the indicators?

    By getting buy-in and participation to the SOLEC indicator process, we hope that agencies/organizations will recognize the necessity of the work and voluntarily "sign-on". In addition, a strong case for new monitoring and collection needs to be made to government officials and binational organizations such as the BEC (Binational Executive Committee).

25. First we believe that the indicator list as given in Appendix 1 defeats the entire purpose and intent of the exercise. It is a list of 80 indicators which are not consolidated in any way. What is needed are a few, e.g., 5 or 6 indicators which can be readily understood by the lay public and the IJC Commissioners. Note the up-front requirement "to establish a consistent easily understood suite of indicators". Many of the indicators will show improvement, many deterioration, and many little change. What do we conclude?

    We are addressing this concern through the potential development of 6-10 indices. However, we need the complete suite of indicators to provide good information to middle management. The Table in Appendix 3 provides several alternative groupings of the SOLEC indicators.

26. Let us express some frustration. Our Centre has worked hard in this area in recent years deriving and advocating the concept of Equilibrium Lipid Partitioning as an ecosystem-wide indicator of levels of contamination. We attempted to present these ideas at SOLEC but the format was not conducive to receiving new ideas. We have presented the concept at IAGLR and a paper on the topic will be published soon in JGLR. In our view this consolidates all the contaminant concerns in one indicator.

    This looks like it could be included in the SOLEC suite of indicators at a future date (and if successful, possibly remove other indicator(s)). In your opinion, how do we make SOLEC more "conducive to receiving new ideas"? We are always open for suggestions.

27. For the less informed reader of the SOLEC Indicators List, is it worthwhile to list "invasive" more such as done in "4513 ... invasive plants"? -- -- such as adding "invasive" to 18 Sea Lamprey, and can it be added to 8134 ... problem species? Adding "invasive" more in the List, where it can be added, may help amplify and focus the Great Lakes ecosystem invasive-and-biological integrity issues to "incrementally" more effectively inform and influence certain readers about needed actions on existing invasives in the Great Lakes ecosystem and/or about needed actions to better prevent new ones from coming in.

    We think there is some confusion between non-native and invasive. Many species are non-native but not invasive, and there are native species that are invasive.

28. I believe SOLEC needs to directly address the issue of data collection and SOLEC's expectations of state agencies. Without funding to specifically collect data for SOLEC indicators, those SOLEC indicators that provide little direct utility to a state agency will not receive priority consideration for monitoring.

    We understand the concern that SOLEC will lead to an unfunded mandate to the states and provinces to collect the data for the indicators, but it is not our intent to dictate programs, nor should any single agency provide all the funding. Rather, the SOLEC indicators are seen to be an means to more efficient monitoring programs with more collaboration and cooperation from all the Great Lakes partners.

29. One limitation is the lack of linkages between the state and pressure indicators. In rare instances are the pressure indicators clearly connected to an identified state indicator. For example, the list includes a contaminant deposition indicator, a contaminant in fish tissue, and a contaminant in sediment indicator (Indicators # 0117-0120). These are very useful indicators, but without concomitant collection of contaminant releases and uses within the basin, the primary sources of the contaminants cannot be addressed. Mercury, for example, is still used and present in process and products within the Great Lakes Basin. Reducing mercury use and releases within the Great Lakes Basin (and beyond) is necessary to begin reducing the atmospheric input of mercury to the Great Lakes. Unfortunately, the SOLEC list lacks any indicators of contaminant use or release within the Great Lakes Basin. This data gap means that states and citizens within the Great Lakes Basin will have limited information to determine the source of contaminants affecting our Great Lakes. [Our Agency] therefore recommends SOLEC include contaminant use and release indicators in the SOLEC indicators list. To affect the condition of the state indicators already identified, users of the indicators must understand the source of the pressure.

    First, we agree that linkages are very important, but explicit cause-effect relationships aren't always known. This is perhaps a future consideration but at this time we are not ready to collect this level of information. It works for mercury because the use of mercury in the basin has a direct effect. Second, it is not the place (or intention) of SOLEC to collect source information at the scale of LaMPs/RAPs/local levels. We work at a different (larger) scale.

30. Other indicators identified lack the ability to support the indirect use envisioned in the indicator description. As written, Indicator #111 (Phosphorus concentrations or loadings in nearshore or open waters) may provide technically useful information, but the concentrations or loadings alone would not support the indirect uses identified. Actual concentrations of phosphorus may not provide direct utility, as the concentration inducing loss of beneficial use is different among the aquatic ecosystems which compose the Great Lakes. The most useful representation would be the phosphorus loadings (relative to local tolerable levels) combined with a measure of the number of days and lake acres impaired due to nuisance algae conditions. Ideally, Indicator #0111 would be linked with the prevalence of nuisance algal blooms or a shift in the predominant phytoplankton species to provide the greatest utility. Though Indicator #109 focuses on phytoplankton populations, the description does not clearly indicate an explicit linkage to the phosphorus loading indicator. Nor does the description for Indicator #109 mention how the phytoplankton population information would be presented in a useful manner to non-technical users.

    See the response to comment 5. We have revised the Purpose statements for all the indicators, but some of the linkages between the indicators remain implied rather than explicit. The table in Appendix 3 presents several groupings of the indicators for which linkages can be identified.

Open and Nearshore Waters

31. The set of indicators identified seems sufficient to provide basin-wide trend information. However, there are no indicators included regarding the direct abundance of introduced or exotic aquatic species, merely some indirect measures such as native unionids.

    We agree. We have received several comments about this, and we are attempting to identify an "exotic species indicator" for the SOLEC list.

32. Which invasive species number category covers the zebra mussel, spiny water flea, river ruffe, and the other bad water invasives?

    Same as for #31.

33. I still think we need an exotics indicator (endpoint zero introductions). Annex 6 of GLWQA would seem to require one associated with ballast. It's certainly in GLFC Vision. Maybe "exotics in lake" plus "target for ballast discharge" (which needs research). Remember that there is such as thing as authorized introductions, e.g., beetle to eat loosestrife, salmon to eat alewife.

    Same as for #31.

34. Isn't a general aquatic animal "health" indicator needed beyond tumors, e.g. it is highly unusual for fish to die of BKD in wild, whirling disease range is spreading, whitefish condition is so low in northern Lake Huron that filleting machines barely work on the skinny things, Glugea hertwigi was a worrisome parasite of smelt there for a while. And EMS. Sometimes, but not always, these are signs of a problem in the lake that needs attention.

    We agree that some sort of "condition factor" may be a good idea, and we would appreciate some suggestions.

35. There seem to be few indicators focusing on predator and prey fish populations. Is there an opportunity to combine these? Would trends in water temperature be an important pressure indicator within this category? It could be linked to climate change but more directly associated with the health of Open and Nearshore Waters.

    We have combined some predator-prey indicators. See indicators #9 (Walleye and Hexagenia) and #93 (Lake Trout and Diporeia).

36. In many instances the quoted end-points have been revised and are no longer appropriate. I think as long as it is recognized the most current management plan or FCGO's indicates the most appropriate end-point then that's all you can do.

    We agree. End points can change, but we still the measurements to support the indicator.

37. Aquatic Habitat (#6). Should indicate in limitations section that in many cases we do not know how to recognize critical aquatic habitat, nor do we understand the relationship between the quantity of habitat and aquatic production. The problem is further compounded by issues of scale such as (cumulative loss, connectivity of habitat between life stages or interacting species).

    We agree. This will be an evolving indicator as we conduct research and learn more about what to measure.
38. Aquatic Habitat (#6). FYI, the GLFC has approved in principle and will edit and revise for December approval the April 99 draft GLFC Declaration for the Conservation and Rehabilitation of Aquatic Habitat.

    Thanks for the reference.

39. Aquatic Habitat (#6). This indicator is useful in that it measures a component of the ecosystem which directly affects the physical, chemical and biological integrity of the lakes, but it may not be easy to measure and interpret. It will be difficult to establish reference points or a desired condition for most of the proposed measurements, e.g., Are good, quantitative historical data on the surface area for the different habitat types available? How much area and how many of each habitat are needed to support healthy populations? How do you objectively measure the quality of each habitat?

    We agree. This may be a research question for a while, but SOLEC recognizes the need for such an indicator.

40. Aquatic Habitat (#6). The description talks only about fish habitat, not about habitat for other organisms such as mussels, benthic inverts, and mollusks. Either the description should be broadened or the indicator changed to Fish Habitat. Also, will the focus be on a variety of habitats for all species or on specific habitat types for a few sport fish?

    We have renamed this indicator Fish Habitat. We have other indicators for benthos (#104) and mussels (#68), for which habitat is inferred.

41. Salmon and Trout (#8). Ecosystem Objective: FYI, in addition to lake trout, the LSC (Lake Superior Committee) has just approved a coaster brook trout rehabilitation plan. Comments: Coded wire tags (??nasal insert tags??) are used mostly on fingerlings and not just "larger fish'. Also, snouts are usual but not only place they're inserted. >>Ouch<< There are several other marking techniques that are used less frequently. Endpoint, Limitations, Comments: endpoints should be those of the duly mandated authorities, i.e., fish community objectives. Those of us who disagree with stocking should either influence states etc. or ask Congress to give feds authority, but a state-of-the-lakes exercise should NOT substitute its own endpoints (e.g., 100 % self-sustaining) for those of duly mandated authorities. To do so oversteps our mandate and invites backlash or non-cooperation in future documentation of indicators. For example, the Lake Huron fish community objectives state, "For most United States waters, stocking will play a large role in maintaining anadromous salmonine fisheries because of a lack of suitable tributaries for spawning." [GLWQA tiptoes up to states rights challenge but does not cross line - check very careful language of Lake Superior lake trout objective. Even if GLWQA did cross line, it would change nothing since GLWQA is not a Congressionally ratified treaty. Canada-Ontario division of responsibilities is much less clear with Canada perhaps having more say than do their U.S. counterparts but having delegated to Ontario -- if I correctly understand the highly nuanced Canadian system.] Endpoint: I'll see if I can get salmonine harvest targets for Superior and Erie. LSC fish community objectives are in progress, and LEC's are being edited. LOC's latest FCOs are also being edited - did you use 1990s harvest targets?

    We agree that endpoints that are already established are best. Sometimes proposed SOLEC indicators force the issue with suggested endpoints. You are correct that SOLEC should not arbitrarily substitute endpoints if others are already accepted.

42. Salmon and Trout (#8). The assertion that the data to support this indicator is routinely collected is not true and is dangerously misleading. Harvest and economic statistics associated with commercial fisheries are collected routinely. However, with the exception of Lake Erie, recreational fishery harvest now dominate the yield in the Great Lakes. Tracking of the yields of recreational fisheries is expensive, and is rarely done on a whole lake annual basis. Reported statistics are often only partial and are associated with high degree of measurement error. Identifying the origin of salmon and trout as wild or hatchery is an added difficulty associated with this indicator as many fish stocked in the Great Lakes are not uniquely marked. Reliable and cost-effective methods for classifying unmarked trout and salmon need to be developed.

Thank you for this information. This indicator needs some clarification by fisheries personnel.

43. Salmon and Trout (#8). These make sense as indicators, but it should be kept in mind that increases and declines in numbers/biomass/productivity may reflect changes in stocking rather than changes in the environment. Comments: In the first paragraph, it is stated that Atlantic salmon have been introduced to the upper four Great Lakes, but the next sentence states that "If Atlantic salmon are introduced to the upper four Great Lakes, they should be treated as exotics." These two statements are not consistent.

    Thank you for this information. This indicator needs some clarification by fisheries personnel. We have clarified the reference to Atlantic salmon introductions in the Comments section.

44. Walleye and Hexagenia (#9). Limitations: Delete "easily" re overfishing. While walleye were being overfished before 1970, I seem to recall some data that showed walleye overshot their preybase in the 1980s in spite of harvest.

    O.K.

45. Walleye and Hexagenia (#9). The description mentions that the goal for walleye is to move toward historical levels in mesotrophic waters throughout the basin; however, this goal may not be realistic considering the introduction and continued stocking of salmon.

    Thank you for this information. This indicator needs some clarification by fisheries personnel.

46. Preyfish populations (#17) Features: In addition to top-down management (predation), preyfish are also heavily influenced by phosphorus management and exotics such as zebra mussel. Climate is also important to exotics' ability to overwinter, e.g. alewife. Comments: LOC-99-1 -- The LOC (Lake Ontario Committee) recognizes a potential window of opportunity for reintroduction of bloater chub. OMNR supports a NYDEC attempt. NYDEC will seek resources. An operation and assessment plan will be written, resources reviewed and sought, and a timeline adopted. LEC-99-8 – The LEC (Lake Erie Committee) recognizes that reintroduction and restoration of indigenous fish species / stocks is a responsibility of the committee, which is comprised of representatives from the fishery management agencies of Ontario, Michigan, New York, Ohio, and Pennsylvania. The LEC accepts this responsibility and will actively, and in a timely manner, address the potential, feasibility, biological implications, commercial and recreational fishing impacts and costs associated with restoration and rehabilitation of species such as lake sturgeon, lake herring, sauger, etc. The LEC may actively seek partners in pursuing restoration efforts, but the LEC will implement and coordinate all reintroduction and restoration programs approved by the five jurisdictional management agencies.

    Thank you for this information. SOLEC wishes to work closely with the Lake Committees.

47. Preyfish Populations (#17). As is the case with the Salmon and Trout indicator, changes in many preyfish populations may reflect changes in predator stocking rather than an environmental change.

    O.K. We need to be careful interpreting the data.

48. Sea Lamprey (#18). Ecosystem Objective, Endpoint: Please mention that 1955 Convention on Great Lakes Fisheries created the GL Fishery Commission "to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention Area." Features: I think the most thorough assessment we do is of "transformers" in order to determine need for treatment before animals descend tributaries to begin predaceous phase. Limitations: While wound classification is subjective (as is for example scale aging) GLFC and cooperating biologists

hold workshops etc. to standardize evaluation as much as possible.

We have revised the indicator description to reflect these concerns, and we continue to request input from fisheries experts.

49. Sea Lamprey (#18). The endpoint measures percent reductions in each lake. What year is used as the benchmark against which reductions will be measured? Some of the targets recommend a 50-75 percent reduction by 2000 (next year). Depending on the benchmark year, this may not be realistic.

    The reductions are based on year-of-issue of the Fish Community Goals and Objectives for each lake. The endpoint field for this description has been revised to clarify this point.

50. Native Unionid Mussels (#68). Would it be better to call them bivalves to include for example fingernail clams? Features: Again, I'm no expert, but does burrowing starve rather than suffocate zebes attached to native bivalves?

    The intent of this indicator really is focused on unionids. By extension, the indicator may infer conditions favorable to fingernail clams, but we cannot measure all ecosystem features everywhere.

51. Native Unionid Mussels (#68). The lack of historical data may make the use of this indicator problematic. We recommend that the endpoint be species distribution rather than abundance (due to the lack of historical abundance data). Also using 12 species as the threshold for healthy sites seems high - healthy sites may have fewer species due to historical patterns of distribution.

    Distribution and abundance are both important features of population statistics.

52. Fish Entrainment (#72). The focus of this indicator seems to be *water withdrawal*, yet it is named "fish entrainment". Overall, the indicator is very confusing.

    We have re-assessed this indicator and combined it with Fish Habitat (#6).

53. Lake Trout and Scud (#93). Ecosystem objective: See diatribe under Salmon & Trout. With "Oligotrophic waters in the other Great Lakes should be similarly maintained", SOLEC again seems to be seeking to create endpoints - which we should avoid. Endpoint: "The objective for lake trout restoration in Lake Superior is to restore self-sustaining stocks that can annually yield approximately 2 million kg (4 million lb), the average annual yield in 1929-1943." (M. Hansen, ed. April 1996. A Lake Trout Restoration Plan for Lake Superior. GLFC) "Lake trout yields may approximate 1.4-1.8 million kg two decades into the next century." (R.L. Desjardine et al. 1995. Fish-Community Objectives for Lake Huron. Spec. Pub. 95-1) Re Lake Erie, the FCOs being edited call for "historical levels". Some unpublished work under Henry Regier suggests that Lake Erie lake trout produced 110,000 lbs. or 50kg annually.

    See our response to #41. We have revised the indicator description to reflect current Fish Community Goals and Objectives.

54. Lake trout and Scud (#93). Features: the statement that there is lakewide assessments annually in each lake is not true. Limitations: the implication that harvest controls are needed to promote sustained use if the species is to be used as an indicator puts the cart before the horse. A management objective is to promote sustained use whether or not the species is an indicator species. The statement that status of D. hoyi populations is generally known and the understanding of changes related to Dreissena mussel invasion is emerging is misleading. In the last two-years it is clear that we have seen catastrophic declines in D. hoyi associated with presence of mussels but the mechanisms are unknown and vary widely in their implications. Not all stocked lake trout are marked so strain comparisons are not always possible. Interpretation: Seems to overstate the simplicity of this indicator. The fact that we are having trouble rehabilitating lake trout in

Lake Ontario does not in itself mean the ecosystem is unhealthy, as it could be related to the availability of appropriate lake trout stocks. If we are successful in establishing a stock of lake trout superbly adapted to the current state of the ecosystem (essentially a state that never existed before with most of the biomass comprised of exotic species at several trophic levels) can we argue that the system is healthy, or just healthier or perhaps sustainably ill? I think a cautionary statement that interpretation of this indicator is complicated by the degree and extent of recent species introductions and ecosystem perturbations would be appropriate.

These are good points that reflect the need to be cautious when interpreting indicator data. This does not negate the value of collecting and reporting the supporting data.

55. Lake Trout and Scud (#93). Lake trout continue to be stocked in the four lower Great Lakes, so using lake trout abundance/biomass as an indicator may reflect stocking practices rather than environmental changes.

    Stocking information will be useful to interpret lake trout abundance data.

56. Deformities, Erosions, Lesions and Tumors in Nearshore Fish (#101) You may (or may not) wish to refer to Tumor Manual at http://www.glfc.org. (Easiest to just use search mechanism for "Tumor Manual" at our website.)

    Thanks for the tip.

57. Benthos Diversity and Abundance (#104). Why is this indicator only limited to species of oligochaeta? Have they responded better to anthropogenic related changes than other taxa? A change in some species of oligochaeta does not necessarily reflect a predictable change in whole benthic assemblages. Why not look at a wider range of benthic taxa (chironomids, plecoptera, etc.) which might provide a more sensitive response to stress and a clearer picture of the relative health of benthic communities.

    We are continually faced with the challenge of not being able to measure everything everywhere. Oligochaets are a diverse group that could provide information from which we can infer more general conditions about the benthos.

58. Phosphorus Concentrations and Loadings (#111) Features Reliable load estimates are needed to interpret lake concentrations and fine-tune and manage as P loadings approach target levels (Article IV, Objective 3.b. of GLWQA). The IJC reports that analysis of loading is not ongoing and reliable. Ongoing monitoring has been eliminated or severely reduced and loading estimates are no longer reliable. There are also problems with reporting and commitment to continue phosphorus load estimates for all lakes. The interruption of lakewide P loading trend data is a particular concern of the Great Lakes Fishery Commission, as reported to Governments.

    Agreed

59. Phosphorus Concentrations and Loadings (#111). It seems that the presence of algal blooms could be used in conjunction with this proposed indicator. The document indicates that a great deal of remote sensing and satellite imagery information is available on algal blooms.

    Agreed. The presence of algal blooms could be reflective of excessive nutrients, but the indicator itself is intended to address the specific pressure of nutrient loadings.

60. Phosphorus Concentrations and Loadings (#111). Lacks adequate focus on phosphorus sources. Though the concentrations and loadings are useful, especially to support the total maximum daily loading efforts, greater utility would be achieved by discriminating the loadings among the primary phosphorus sources (i.e. permitted point sources, agricultural sources, urban runoff sources, natural loadings, etc.). The loadings so discriminated would allow users of the indicators to identify where to focus attention to reduce phosphorus

loadings.

To the extent that general categories of sources are known, we can report them, i.e., tributary loads, point sources, etc. The scope of SOLEC indicators, however, would be to combine many local measurements into a more general assessment of Great Lakes conditions. The localized data could be used by states or other more local authorities to influence environmental management actions.

61. Contaminants in Recreational Fish (#113). Finding an endpoint or target concentration for this indicator is likely to be contentious because states use different levels to trigger consumption advisories. One approach may be to choose as an endpoint the fish tissue concentration that relates to the attainment of Great Lakes Initiative standards, rather than using advisories as a target.

    As we have responded to other comments, SOLEC does not presume to set endpoints, but rather endpoints provide the frame of reference to interpret the indicator data. If an endpoint is contentious, it may be reflective of a larger debate being played out across the basin.

62. Atmospheric Deposition Of Toxic Chemicals (#117). This indicator may fit better under the Unbound Indicators group since the sources of contaminants can originate well outside the Great Lakes basin.

    Perhaps. Indicators #117, 118, 119 and 120 really go together as a package, however.

63. Contaminant Exchanges Between Media (#120). These measurements make for interesting science but seem redundant given that contaminant levels in all other media are proposed as indicators. We recommend dropping this indicator.

    We think the approach taken by this indicator has merit, but it may require additional research and testing to be fully appreciated and useful to managers.

Coastal Wetlands

64. All the wetland indicators are good, but some will be tedious and others will be costly. The bigger problem is that many cannot be set in concrete because inverts, fish, amphibians, and birds among others are dependent on plant communities for habitat. Those plant communities can change radically from year to year depending on water-level fluctuations and without any change in human impact at all. Since these changes are natural, any indicator metrics would have to be scaled according to water-level history leading up to the date of data collection. This could be VERY difficult and confusing. It could also mean that nobody would use the indicators.

    We recognize that many changes in wetlands are natural, and that many relate to water-level fluctuations. We hope to distinguish the natural changes from the human-induced changes. You are correct that this task will be difficult and confusing. As a recognized expert on the subject, would you be willing to offer advice and figure out how to best do this?

65. For coastal wetlands it is suggested that one of the criteria for selection of an indicator is that monitoring can be done by volunteers. I would suggest that this criteria would eliminate many (e.g. coastal invertebrate community, coastal wetland fish community health, deformities/eroded fins/lesions/tumours in coastal wetland fish, etc) of the proposed indicators.

    We are suggesting that where possible, monitoring be conducted by volunteers, but acknowledge that this will not be possible for all of the indicators. Using volunteers was not a criteria for the selection of the indicator, but rather a way of operationalizing the monitoring

required to report on the indicators where possible. The added bonus of using volunteers is to build community support for SOLEC, Great Lakes cleanup and habitat conservation.

66. The presence of non-native species might be considered as a pressure on the health of coastal wetlands.

    We did address the presence of non-native plant species in the context of invasive plants (#4513), and elected not to limit our monitoring to non-native species, but to also include invasive native plants as well. We do not have an indicator specifically for non-native non-plant species, such as carp, zebra mussels or ruffe, but this information will come out as part of looking at invertebrate, fish, amphibian and bird populations.

67. The endpoints for most of the indicators listed in this category have yet to be defined and will require a great deal of effort and research to finalize.

    We acknowledge that most of the endpoints have yet to be established and that there will be much work required to do this. In part, there is simply not the history of science and research for coastal wetlands that exists for many other ecosystem indicator groups such as human health.

68. The biological indicators such as CW Invertebrate Community Health (#4501), CW Fish Community Health (#4502), Amphibian Diversity and Abundance (#4504), Wetland Dependent Bird Diversity and Abundance (#4507), and Presence, Abundance and Expansion of Invasive Plants (#4513) are certainly all useful, but they are subject to a lot of natural variability due to natural water-level fluctuation patterns.

    We acknowledge this and hope to be able to distinguish the effects of natural and human-induced stress on these communities. Again, we would welcome your advice on how to best accomplish this.

69. DELT (#4503) and Contaminants in Snapping Turtle Eggs (#4506) could be important in some of the bad sites but may not mean much in uncontaminated areas.

    This may be true, but for the wetlands which are in urban and agricultural landscapes, we wanted to capture contaminants as a stress on wetlands as well as their effects. For example, using snapping turtles as a top-predator that does not migrate very far will integrate the effects of a suite of contaminants.

70. CW Area by Type (#4510) and Gain in Restored CW by Type (#4511) are good generic indicators, but they again are subject to water-levels, as noted in the write-up. I am glad to see recognition that wetland types differ because the biological indicators above will differ somewhat between wetland types.

    Again we hope to be able to distinguish the effects of the natural from the human-induced stresses for these indicators, and would welcome your advice.

71. Coastal Wetland Area by Type (#4510). The endpoint for this proposed indicator is no net loss; however, the year that will be used as the baseline is not mentioned.

    You are correct, the selection of the baseline year still needs to be discussed.

72. Gain in Restored Coastal Wetland Area by Type (#4511). This indicator could be misleading. While a gain in restored wetlands might normally be thought of as positive, it also could indicate an increased loss or degradation of natural, high-quality wetlands, followed by their restoration to a quality lower than the original.

    The intent was that this indicator would capture the efforts to restore wetlands that were lost some time ago, rather than current permitted compensation projects. We acknowledge the need to clearly distinguish wetland area and wetland quality. We hope that the other

indicators in the suite will be able to pick-up on the question of quality of the restored areas.

73. Presence, Abundance and Expansion of Invasive Plants (#4513). In the interpretation, if a ranking is developed the "combined score" could also consider factoring in whether the invasive plants are alien/non-native/exotic or native. The invasion of alien species is well recognized as a key threat to Canada's native biodiversity, and the lower Great Lakes basin is one of the principal areas where this threat is being felt. The distinction between native and alien has been made in Indicators #0109, #8129 and #8134.

    We certainly intend to look at non-native invasive plants in this indicator, but also want to acknowledge that the expansion of invasive native plants also indicates stress on wetlands. We have modified the interpretation of the indicator to specifically include native and non-native as a factor.

74. Sediment Flowing into C W (#4516) and Nitrates and Total P into C W (#4560) could be rather difficult to measure accurately for a wetland as a whole. Where do you measure?

    The intent was to use existing (USGS and Environment Canada) networks of tributary monitoring stations, upstream of coastal wetlands for these indicators. These would indicate land use changes in the watersheds of coastal wetlands as well as the stressor of sediments and nutrients themselves.

75. Nitrates and Total Phosphorus Into Coastal Wetlands (#4860). The purpose of this indicator needs clarification. It states "to determine instances of non-excessive nutrient levels in the wetlands", whereas the subsequent text indicates that "excess nutrients can be detrimental to the health of coastal wetlands".

    Although nutrient levels will be monitored to determine excessive or non-excessive levels, in the interpretation, instances of non-excessive nutrient levels (or absences of excessive levels) will be reported rather than the concentrations themselves.

76. Sediment, nitrate, and phosphorus loads into wetlands should be flow-normalized, since observed differences between years could be due to changes in flow from one year to the next.

    We acknowledge the potential for changes being due to flow rather than load. If by 'flow-normalization' you mean using stream-specific and regularly updated relationships of flow and sediments, we believe that the current tributary monitoring system in place by USGS and Environment Canada addresses this and separates the changes in loadings from the changes in flow.

77. I like Water Level Fluctuations (#4861) because it obviously points out that Lake Ontario flunks.

    Thank you.

78. Habitat Adjacent to Wetlands (#7055) is a bit subjective but has considerable value.

    We acknowledge the subjectivity, but also think that using it as an indicator will provide useful information.

79. There are applications for Extent of Hardened Shoreline (#8131) and Artificial Coastal Structures (#8146) to wetlands because they partially determine the supply of littoral sediments to maintain barrier beaches that protect many wetlands.

    We acknowledge this, but have let the Nearshore Terrestrial group be the lead for these two indicators.

Nearshore Terrestrial

80. Area, Quality and Protection of Special Lakeshore Communities (#8129). The term "special" is applied very subjectively in this indicator. All naturally occurring lakeshore communities are important ecologically, but 12 specific types have been selected for the indicator because of particular properties, which may include rarity, uniqueness or sensitivity. The "special" aspect can be noted once in the text but does not need to be in the title and repeated throughout the indicator description (15 times altogether). Suggest omitting the word "special' from the indicator title, i.e., ...Protection of Lakeshore Communities.
    We agree

81. Nearshore Plant and Wildlife Problem Species (#8134). It would be preferable to use "Plant and Animal" as wild plants are also a component of Canada's wildlife. In the report, *A Wildlife Policy for Canada*, the Wildlife Ministers' Council of Canada defines **wildlife** as the following: Pertains to all nondomesticated living organisms. It includes not only vertebrate animals (mammals, birds, fish, amphibians and reptiles) but also invertebrate animals, vascular plants, algae, fungi, bacteria and all other wild living organisms (Wildlife Ministers' Council of Canada. 1990. *A Wildlife Policy for Canada*). Thus, the word "wildlife" in the indicator title should be replaced by "animal", i.e., ... "animal problem species".
    We agree

82. Contaminants Affecting Productivity of Bald Eagles (#8135). "Measure: 1) Concentrations of DDT Complex (including DDE, a breakdown product of DDT), PCBs, PCDD, PCDF and other organic contaminants ...". At first mention, it should be clarified that the initials PTS stands for persistent toxic substance.
    We agree. PTS is also used in other indicator descriptions, and it is included in the list of acronyms in Appendix 6.

Land Use

83. The indicators: water consumption, energy consumption, wastewater pollution and solid waste generation, currently listed under the human activities or response category should be included under the pressure category since they are not measuring programs or efforts to improve the situation.
    O.K.

84. Many of the indicators proposed for this category will be very difficult to measure and many factors other than environmental ones may contribute to changes. Some indicators that seem susceptible to this problem include brownfield redevelopment, mass transportation, green planning process, and energy use.
    We agree. Many of these indicators require refinement and testing.

85. Urban Density (#7000). Endpoint: "There is no conceivable upper end to urban densities from an ecosystem perspective since higher densities are associated with improved urban efficiency and reduced stress on the rest of the ecosystem. Thus, higher densities are better." These are highly arguable statements. "From an ecosystem perspective", it seems inconceivable for there to be an infinitely high urban density. Higher densities can be associated with certain urban efficiencies, but they are not certainties. Further, increasing densities can lead to concentrated environmental stresses that can affect

surrounding ecosystems (e.g., ground-level ozone that spreads into rural areas and higher amounts of municipal wastewater and solid waste that get disposed of in "the rest of the ecosystem"). Higher densities *may be* better in some regards, but it is not a "given" that they "are better".

We recognize that this indicator needs further development, data collection and testing, and we welcome specific suggestions to consider.

86. Land Conversion (#7002). The suggestion is zero change and the implication is that all conversion is some sort of sprawl. I would think that in some cases land conversion would be desirable and that not all conversion will be sprawl.

    There is no intention to imply that all land conversion is sprawl.

87. Brownfields (#7006). What constitutes a brownfield?

    We have included a more explicit definition under "Features."

88. Mass Transportation (#7012). This indicator would not be sensitive to any change in the numbers of people walking or bicycling to work or tele-commuting. Eventually this indicator should be supplemented with estimates of actual automobile use for commuting. It is probably a reasonable indirect measure for the time being. New vehicle surveys, conducted by Natural Resources Canada and Statistics Canada may be helpful in the future.
89. Mass Transportation (#7012). This is a useful indicator, but as expressed, the indicator will provide marginal utility. A measure of mass transportation use supplies only one piece of the complex issue around private motor vehicle use and urban commuting. Complimenting the mass transportation indicator with measures of average commute time and distances within urban areas near the Great Lakes will provide a much more useful picture of the system. Also, providing measures of the increase in urban population relative to the increase in urban/developed land will show the degree of pressure being placed on the system by conversion of land to urban uses. Such information would provide insight on the factors behind the use of private motor vehicles in urban areas within the Great Lakes Basin.

    Mass transit numbers are relatively easy to get. As for other Land Use indicators, this one is evolving. Suggestions like these are welcomed.

90. Only one indicator (#7028) deals with agriculture. You should be aware that AAFC has been working to develop environmental indicators for agriculture. A publication presenting the results of this work is being prepared for release this fall. Should your initiative wish to further develop its treatment of agriculture, you may wish to consider/draw on our approach.

    Thanks.
91. There is only one indicator related to agriculture, "Sustainable Agricultural Practices", #7028, which is a response indicator. It seems to be unrelated to any state or pressure indicator, so the questions arise: What is it a response to? Which pressures is this response supposed to alleviate? Which deteriorating state to improve? Which indicator measures whether the response is effective? Agriculture plays an important socio-economic role in the basins of the lower Great Lakes and is probably the most significant source of transformation of land in these basins and a source of phosphorus, nitrogen, pesticides and other substances. It is estimated that it contributes over 50% of phosphorus loadings and most pesticide loadings to the lower Great Lakes. It can also be a major source of contamination of rural drinking water. A single "response" indicator seems insufficient and at least pressure indicators are required to describe the impact of

agriculture on the Great Lakes ecosystem. Which pressures should be represented depends on the goal of the SOLEC indicator initiative. If the goal is to provide tools for management, then indicators for pressure, related state, and response should be available. If the goal is to have indicators relevant to the GLWQA, then indicators related to the objectives of the GLWQA (in this case phosphorus and toxic pesticide loadings) should be available. If the goal is to assure that the SOLEC agricultural indicators will actually be monitored, then the indicators should be coordinated with those being developed by Agriculture/Agrifood Canada and with past and current monitoring efforts of Agriculture Canada, the Natural Resources Conservation Service/USDA, and the USGS. As a last point, it may be useful to point out that most pressures caused by agriculture on aquatic and terrestrial ecosystems originate either from soil loss due to cropping practices or to manure production due to animal husbandry. Thus a single indicator of "farmland intensity" would be too general to be useful. Livestock density and cropping intensity or quantities partially derived from the former (e.g. estimated soil loss and manure production per unit area) may be useable pressure indicators.

92. The 3 goals listed in the 9th Biennial Rpt. on GLWQA should be reflected in the SOLEC indicators, i.e. Conservation Tillage ac., Buffer-strips mi., & Herbicide applications. These 3 are all tracked by USDA-NRCS, CTIC & USGS. In addition, the new EPA emphasis on animal waste will be targeted (& tracked) through an increase in issuance of NPDES permits. NRCS & others will be developing Comprehensive Nutrient Mgt. Plans (CNMPs) for all livestock operations over the next few years as called for in the U.S.-Clean Water Action Plan. These are the bare minimum that will be needed for SOLEC. The NRCS does a 5 yr. Natural Resource Inventory (NR)) & an annual Work Load Analysis (WLA) that can also be a valuable source of historic data base & trends in AG.

    These are good points, and we anticipate much further development and refinement of this indicator. If ready-made indicators are available, we will take a look at them immediately. We added some text under "Unfinished Business" showing the need to develop indicators for conservation tillage, buffer strips and herbicide application. The AAFC indicators may be very useful, especially if data are already being collected.

93. In addition to urbanization, climate has a large role in land use change through its influence on agricultural intensification. An indicator that describes the influence of climate on land use change would be useful, especially as an early warning or predictive indicator. (We can provide further details)

    The influence of climate change should show up over time in the Land Conversion indicator (#7002).

94. Water Consumption (#7056). On what basis is 50% reduction chosen? Re waste water it may not only be a matter of reducing the amount of waste water but also dealing with effective treatment.

    The 50% reduction endpoint was chosen to elicit some discussion. We would like suggestions for alternate, supportable endpoints.

95. Water Consumption (#7056). Instead of estimating wastewater volumes indirectly based on a direct measure of water usage, wastewater discharge volumes should also be quantified directly, since most wastewater flow rates would be documented on provincial certificate of approvals for effluent discharges. Hopefully, heated water is covered as wastewater, since large volumes of cooling water are discharged into the Great Lakes by nuclear power plants and other industrial plants.

    We looked at wastewater volume as an indicator, but we think that water consumption is the better measure. The indicator description refers to water use, not just permanent extraction.

96. Water Consumption (#7056). I would just like to ensure that you are aware that this

indicator on water use is very important and we expect that it will become even more important in the future. The IJC is currently considering Water Uses and Diversions under a reference. As well as the need to know about the quantity of water used, the discussion about diversions is putting considerable emphasis on water conservation. This will need to be tracked.
Thanks. We'll keep this indicator. It is now called Water Withdrawal.

97. Energy Consumption (#7057) - seeking additional input from Ontario Hydro on this indicator. As good as KWH are as an indicator I think it should be coupled with KW demand as well. Seeking additional information and will pass on.
Thanks for your help.

98. Wastewater Pollution (#7059). The description in the front section (section 4.2.1) of the document lacks specificity of those pollutants that would be measured by this indicator. The specific pollutants are listed in the appendix 1 description, but the initial description leaves the reader with a question as to the specific pollutants targeted by the indicator. In addition, the measure has limited utility as presented. As described, the loadings would be presented without context to the size of the wastewater treatment facility, the size and characteristics of the facility's service area, and the relative contribution or the facility the pollutants released in the local or regional area. Also, ignoring the facility's disposition of biosolids may under-represent the problems posed by pollutants, such as mercury and other heavy metals, which are typically associated with biosolids. The releases of pollutants from the biosolid disposal practices, especially incineration, may be larger than the amounts of pollutants released in a facility's effluent.
We agree that this indicator needs refinement. Initially, the details for this indicator may depend, in part, on what data are available. From an ecosystem viewpoint, the absolute quantity of loadings is the item of interest. From the perspective of a regulator or treatment facility operator, the context for the magnitude of loadings may have a bearing on management decisions.

99. Solid waste (#7060). How is solid waste defined as many jurisdictions differ in what they allow into their waste stream? For example are yard wastes and organics included? What about construction materials? Are these items solid waste or resources?
We agree that this indicator needs refinement. Initially, the details for this indicator may depend, in part, on what data are available

100. Streamflow (#8142). We believe that this is a good indicator, but the endpoint listed in the document, "Functioning longshore transport processes necessary for healthy coastal ecosystems," is not a quantifiable endpoint. Desired flows must be determined for each stream/river that is assessed.
We agree that the endpoint is not quantifiable at this time. We have renamed this indicator as Sediment Available for Coastal Nourishment to more accurately reflect its intention.

101. Streamflow (#8142). We are not convinced that Indicator #4175 (Drinking Water Quality) adequately addresses Annex 16 of the GLWQA, "Pollution from Contaminated Groundwater." Groundwater can be important in sustaining surface water quality/quantity. The IJC Indicators for Evaluation Task Force recommended that "Quality and Quantity of Stream Base Flow" be used as an indicator related to Annex 16. SOLEC indicator #8142 should, therefore be expanded to include base flow reporting and trend analysis.
Indicator #8142 was clarified to reflect Sediment Available for Coastal Nourishment. There is

currently no SOLEC indicator for tributary flow. We are aware that SOLEC may need to look more closely at tributary monitoring and related issues.

Human Health

102. All the human health indicators are good ones and both parties are commended for developing this list. The indicators assess exposure but provide little in the area of human health effects.
We agree that health effects indicators need to be developed.

103. Indicators of health effects related to human exposure should be another indicator - markers of biological effects. Even though considerable research is required to establish this relationship, there already exist two established research programs which are ongoing in the U.S. and Canada, both investigating the potential for adverse human health effects from exposure to PTSs.
We agree that health effects indicators need to be developed. At this time, the health effects work is largely research-based and there is a need to translate that research into indicators. Some indicators have potential, for example, those relating ambient air pollution to hospital admissions.

104. For the human health indicators there should be a clear statement about at-risk or susceptible populations. The research findings of the ATSDR Great Lakes Human Health Effects Research Program have shown that body burden levels of persistent toxic substances (PTSs) in populations in the Great Lakes basin are similar to the general population. However, the body burden levels of at-risk populations, i.e., sport anglers, Native Americans, the elderly, etc., are much higher than the general population. There should be a focus on these populations as the indicators are pursued in the Great Lakes and St. Lawrence Basins. There should be another category or indicator for at-risk populations.
Some indicators will attempt to look at at-risk populations separately from the general population. For example, indicator #4177 (Chemical Contamination in Human Tissue) will incorporate at-risk populations, and reference to that effect is in the Comments section of the indicator description.

105. Indicators of well being or societal health should be reconsidered as an indicator for human health. This indicator can gauge population attitudes, knowledge, behaviors and perception of risks to elements in the Great Lakes and St. Lawrence River basins.
We agree that indicators of well being or social health need to be present. Under SOLEC, well being and social health indicators have been incorporated into the Societal indicators. Societal indicators need both thought and development.

106. The SOLEC indicators selected should reflect spatial and temporal scale and should also include historical data as well as currently collected material so that longer term trends can be reported, e.g., *8135, #8150, #4167(?), #4506 and many others.
We agree. That is the intent of the SOLEC indicators.

107. Fecal Pollution (#4081). While this would be a valuable indicator, getting agreement on an endpoint may be difficult given that some states have standards for E. coli while others use fecal coliform.
We agree that this will be a continuing challenge. There is some activity nationwide in the

U.S. for the adoption of uniform E. coli standards and methodology. We have renamed this indicator E.coli and Fecal Coliform Levels in Nearshore Recreational Waters.

108. Fecal Pollution (#4081). Under the Limitations section, a comment on variability related to changes in weather patterns from year to year would be appropriate. In many locations this variability is the primary reason for year to year change in bacterial counts. ***The suggested statement was added to the indicator description.***

109. Chemical Contaminants in Fish Tissue (#4083). This is redundant, as this indicator already is proposed as an indicator under Nearshore and Open Waters. ***The two indicators are different. #4083 is simpler and more direct, i.e., reporting concentrations of contaminants in dorsal muscle from selected fish species, and some data are currently available. #113 calls for developing an index of contamination based on relative proportion each species contributes to the total annual catch. #113 requires further development, including some modeling, but it may be the foundation for a useful, general index.***

110. Chemical Contaminants in Fish Tissue (#4083). There is no indication of which PBTs should be measured. Although the standard routine is to measure concentrations of contaminants in skinless, boneless fillets, most of he contaminants of concern concentrate in the fat. It is incorrect to assume that most fish-eaters eat only skinless, boneless fillets. Measuring concentrations in the fillets may be the most accurate way to determine trends, but the concentrations in fillets will underestimate the dose of many contaminants in terms of dietary intake. ***The PBTs suggested for measurement are those targeted by the Great Lakes water Quality Agreement (see Measure statement), along with those identified by the LaMPs and Binational Strategy for Toxics Reduction.. Principally, those would be PCBs, DDT/DDE, dioxins, dieldrin, chlordane, hexachlorobenzene, toxaphene and mercury.***

111. Chemical Contaminant Intake from Air, Water, Soil, and Food (#4088). We recommend dropping this indicator. Other proposed indicators include contaminants in fish, drinking water, and air. Therefore, this indicator is redundant. ***The Air Quality Indicator (4176) deals with "smog" constituents rather than the PBT chemicals referred to in 4088, thus they are addressing altogether different parameters. In addition, there is no soil or food (other than Great Lakes fish) indicator in the current suite. Other indicators include concentration of contaminants in various environmental compartments. However indicator 4088 combines the data into a multimedia exposure assessment. The indicator requires further development, but it could be one that is closely followed.***

112. Chemical Contaminant Intake from Air, Water, Soil, and Food (#4088). Some of the exposure indicators are too broad in scope and will take considerable time to accomplish to provide answers in a timely 3-5 year period. For example, The purpose of Indicator #4088 is to estimate the daily intake of PBT chemicals from all sources and determine if the values for the PBT chemicals are below established guidelines. Are there established guidelines for all PBT chemicals in all the media mentioned? IF not, it will take time for all parties to agree on these values. The text indicates that some of these contaminants have been estimated in Canadian diets for various age groups. Would these values be true for the American diet? This indicator for human health is good and should remain, but a more stringent strategy should be developed which would be more cost effective and obtain measurable results in a timely manner for the citizens of the Great Lakes. ***We agree that 3-5 year is a short period to provide answers in a timely manner. However, we recognize that the development and use of indicators is long term effort. With regards to***

guidelines, Canadian Tolerable Daily Intake (TDI) guidelines are available for most PBT chemicals.

113. Drinking Water Quality (#4175). SDWB [U.S. EPA, Region 5, Safe Drinking Water Branch] main concern is that any drinking water indicator adopted by SOLEC, Lakewide Management Plans, and Remedial Action Plans be based on ambient water meeting human health water quality criteria rather than treated water meeting maximum contaminant levels (MCLs) and treatment techniques of the National Primary Drinking Water Regulations. Measure: The reference to treated and distributed drinking water data should be removed. The reference to drinking water disinfection by-products (e.g., trihalomethanes) in treated drinking water should be removed, or replaced with measures of disinfection by-product precursors in ambient water, e.g., total organic carbon. Turbidity should be added to the list of contaminants. Excessive turbidity can overwhelm filtration with break through of protozoan pathogens to finished drinking water, and interfere with the disinfection process. The reference to alkylphenols should be removed, because these are still basically investigatory in nature and are not currently regulated. Ecosystem Objective: This should be modified to make it clear that the objective is related to ambient water meeting human health water quality criteria, not to treatment in drinking water treatment plants. Features: The references to treated and distributed drinking water data should be removed.
There is some debate about drinking water being assessed as ambient (raw), finished, or distributed. Perhaps some items are best measured at different locations. For example, turbidity in raw water, pathogens in finished water, and lead in distributed waters. A workshop was held in August, 1999, to more clearly define the elements of drinking water indicator(s), and for SOLEC and the IJC to reach consensus on priorities for monitoring and reporting on drinking water quality. Results of that workshop are being used to better define the measurement for this indicator.

114. Drinking Water Quality (#4175). The Endpoint of this indicator states, "Densities of disease-causing organisms or concentrations of hazardous to toxic chemicals or radioactive substances should not exceed human health objectives . . . or guidelines. We have not read what the human health objectives are in this document. These objectives need to be identified in section 4.5 Human Health.
We did not explicitly state the drinking water guidelines or objectives. In Canada, Canadian Drinking Water Guidelines and Ontario Drinking Water Guidelines exist for over 100 parameters and may differ with individual State standards. This indicator could handle reported contaminant data from treatment plants obtaining their raw water from ground sources. Obtaining contaminant data for Individual wells serving individual homes is problematic.

115. Air Quality (#4176). The trends could also be illustrated spatially using GIS which would show changes before and after the implementation of government, industry or community initiatives. Since the relationship between adverse respiratory effects (e.g., hospital admissions) and air pollutants such as ozone has been established for the Great Lakes region (or at least provincially), it may be useful to show the annual number of pollutant increments as illustrated in the British Columbia air quality reports. For example, for each 10 ppb increase in ozone levels (above a specific level), there is an equivalent percentage increase in respiratory-related hospital admissions. Thus, each increase of 10 ppb is considered an increment. By showing the annual number of pollutant increments for a specific area over a given time period, the pollutant levels are portrayed in a human health context. It also avoids the problems associated with different standards or objectives for various jurisdictions.

Thanks for the suggestion. We will consider it.

116. Chemical Contaminants in Human Tissue (#4177). This indicator would measure PBT in human tissues such as blood, breast milk, hair, and adipose tissue. We would also add urine to this list. Under Comments please add the following: The Agency for Toxic Substances and Disease Registry Great Lakes Human Health Effects Research Program has determined body burden levels of various PTSs in at-risk populations. These body burden levels for some PTSs are 2 to 4 times greater than the general U.S. population. Reference: Johnson et al., 1998. Public Health Implications of Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins. J. Great Lakes Res. 24(2):698-722.
"Urine" was added as a component, and the reference was added to the Comments section.

117. Radionuclides (#4178). This indicator will not enable one to measure ecosystem effects. From a human health perspective, direct measurements of tritium instead of relying of the beta counts for air, water, and precipitation would be very valuable. The absence of alpha monitoring is also noted. This picks up the uranium and thorium related isotopes, including plutonium (which because of its half life of billions of billions of years, is essentially forever once contaminating a system). Also Co-60 should be considered in the list of nuclides. This nuclide has a 5 year half life and is one which is widely used in chemotherapy and other medical situations. Some lakes with unusual cobalt levels are examples of a lack of radioactivity monitoring because cobalt is very rare geochemically, and the only explanation for the high cobalt levels found in these systems is the radioactive decay of iron and nickel isotopes (from nuclear power plant emissions) and direct inputs of radioactive cobalt from hospitals and nuclear medicine groups to a feeder stream to these waterbodies.
We agree that this is an indirect measure of environmental and human exposure and have acknowledged the limitations of this indicator in the text. We currently don't have a great deal of expertise on the Health Core group to appropriately respond to the radionuclide indicators issues and need to find an advisor. It should be noted that this is the only indicator pertaining to ionizing radiation and radionuclides that was proposed throughout the SOLEC process.

118. Geographic Patterns and Trends in Disease Incidence (#4179). The incidence of certain kinds of acute health-related events (e.g., hospital visits for asthma attacks, miscarriages, birth defects, etc.) could be considered as complementary to this indicator.
Thanks for the suggestion.

Societal

119. There may be some measures that have been suggested in the literature as a means of getting at quality of life as part of the state indicators. Some examples include: Mortality pre-age 65, Suicide rate, Greenspace per capita, Accident rates, Crime rate, Literacy rates, Percentage of labour force employed, Estimates of homeless population and Percentage of households with income below low income cut-off.
We would like to incorporate quality of life aspects from a positive health perspective in an aesthetics indicator.

120. Most of the listed parameters in this category will be subject to considerable and unresolvable interpretations as to what impact a change in any one will have on the

Great Lakes environment. Two separate documents, one dealing with environmental and one dealing with societal factors or at least a much clearer differentiation between the two in a single document would be more useful.
Please see our response to General Comment #22.

121. The inclusion of Societal Indicators to the SOLEC effort is a bold and welcome addition. The MPCA [Minnesota Pollution Control Authority] also realizes the need to connect environmental improvement and protection with economic and social conditions.
Agree. Thanks for the comment.

122. A number of the indicators under the Societal section represent useful measures of the integration of an environmental ethos within the Great Lakes Basin. What appears to be missing, though are measures which indicate the impact of healthy Great Lakes on local and regional economies. One suggested measure of this impact is the relative percent of a local or regional economy dependent upon Great Lakes based tourism. The North Shore portion of Lake Superior provides an example of the tourism value of a pristine Great Lake to the regional economy.
We agree. Good advice. We will consider this as we further develop societal indicators.

123. The economic value of the Great Lakes could also be expanded to show the non-tourism dependence of a local or regional economy and social structure upon a healthy Great Lakes ecosystem. Uses such as drinking water sources, shipping of goods, fishing could all be integrated into a percent of the regional or local economy and social structure that depend on the Great Lakes.
We agree. Good advice. We will consider this as we further develop societal indicators

124. Also lacking from the Societal Indicators list are indicators of population changes within the Great Lakes Basin. A primary threat to the Great Lakes is the increasing populations in urban areas within the Great Lakes Basin and concomitant changes in land use. Indicators used to report the issue of urban sprawl would prove useful in the Societal category. Measures of the amount of green space in Great Lake urban areas, the number of National, State or Provincial parks near the Great Lakes, recreational trails (hiking, biking, canoeing, kayaking, etc.) near the Great Lakes, as well as the population and demographics of those living on the Great Lakes would show the value society places on healthy Great Lakes.
We will deal with this issue in terms of conversion of land for commercial or residential land. This is a pressure.

125. General societal pressures upon the Great Lakes could be shown by displaying the number and location of releasers of toxic chemicals in the Great Lakes Basin (from the USEPA TRI and EC equivalent). The percent of local or regional economics dependent upon companies releasing toxic chemicals within the Great Lakes Basin would further show the systemic relationships between socio-economics and the state of the Great Lakes. Another societal pressure indicator would be the number, size (i.e. gallons per day of discharge) and location of wastewater treatment plants discharging to a Great Lake or a tributary of a Great Lake. Specific for mercury, a pressure indicator could depict the percent of energy produced, imported or consumed within the Great Lakes Basin that was produce through coal combustion.
We will consider these suggestions under Land Use indicators.

126. Positive indicators flowing from the above mentioned pressures could include the

number of companies within the basin that have environmental management systems (i.e., ISO 14000). Concerning wastewater treatment facilities, the number of facilities with toxics reduction plans would show the movement towards pollution prevention within the Great Lakes Basin.
Indicator #3513 deals with this.

127. Citizen/Community Place-Based Stewardship Activities (#3513). Good broad indicator. Maybe could track government spending (funding through grants, etc) as a measure of activity or lack of the same??
***Indicator #8140* addresses this.**

128. Aesthetics (#7042). Good broad indicator - very hard to qualify - even more difficult to quantify - Maybe able to capture some aspects of this indicator through documentation of Spills (aquatic and terrestrial) - as tracked by OMOE.
Please see our response to comment 119, dealing with Quality of Life.

Unbounded

129. Could UV radiation input to the Great Lakes basin be a worthwhile unbounded indicator?
***We are not sure if this would be useful, but we would welcome advice on the matter. Maybe some kind of UV rating or index related to human exposure would work. Perhaps this topic could be discussed at a future SOLEC* breakout session.**

130. The term "unbounded" sounds like miscellaneous, maybe these could be called global.
We have struggled to find the right descriptor for this category. It is not miscellaneous. The indicators have a geographic scope on the scale of the whole Great Lakes basin or larger, i.e., regional, continental or global, hence the "unbounded" term.

131. There is a problem with nomenclature and the use of the phrase *Global Warming*, since the indicators being suggested are in fact nothing more than measures of short term variations of weather. Global warming and/or cooling is a phenomenon that is better measured in terms of geologic time frames. A renaming of those indicators and a revision of their descriptions would be appropriate.
Good point. We will use the term Climate Change instead of global warming.

A9.2 Positive Feedback

1. It is obvious that an impressive amount of work went into the development of indicators that reflect the state of the waters and shorelines of the Great Lakes. The current suite of indicators are quite comprehensive in describing the state of the waters and take advantage of existing monitoring programs where possible. Careful thought has been given to developing indicators that incorporate change or can indicate change.

2. An impressive amount of work went into developing these indicators. The indicators are quite comprehensive and geared towards change.

3. ...recognized high level of scientific integrity. This effort is notable and very much appreciated.

4. Congratulations on making substantial progress -- -- which should be reported on in future key US-Canada high-level meetings.

5. The indicator development process is thorough and inclusive, especially in bringing together the necessary expertise. The selection of indicators document is an excellent resource. In most cases, the indicators themselves seem to capture the key ecosystem health issues related to the Great lakes.

6. We commend the State of the Lakes Ecosystem Conference (SOLEC) Steering Committee on its extensive efforts to identify environmental indicators and produce this document. [This agency] recognizes the need for relevant, scientifically credible environmental indicators for the Great Lakes.

7. Overall, the draft report is an excellent first step in identifying meaningful and measurable parameters that can be used to assess and track changes in the Great Lakes system. Most of the indicators in the various categories have some scientific foundation in that a direct or indirect relationship can be ascribed over time between the indicator and changes in the overall quality of the Great Lakes environment.

8. This version of the indicators represents a commendable evolutionary step in the process to identify indicators for the Great Lakes Basin. The range of issues and spatial size of the basin pose challenges to the compilation of a comprehensive list of indicators. The broad range of potential users also creates a substantial challenge to effectively meet a diversity of information needs.

9. I wish to commend the various committees on focusing on basin-wide issues. The spatial scale of the indicators shows that the committees were very cognizant of the need to maintain a focus on the entire Great Lakes Basin. This geographic scale allows [this agency] to contribute to and benefit from coordinated efforts throughout the Great Lakes Basin.

10. They have changed the format of the descriptions to make the definitions and criteria more useful.

11. I think there was an applaudable effort to find indicators that could serve a variety of purposes and offer a basin snapshot. It is a positive step to strive for measures of basin-wide health.

12. From an agency response perspective, I think that we can congratulate the SOLEC team on their effort, recognizing that experts and agencies still have a ways to go in fine-tuning indicators and collecting the appropriate information.

13. As an agency we should strongly support the move towards the development and use of standard indicators of ecosystem health. This applies not only to the Great Lakes but also to inland waters. This initiative is a step in the right direction and is essential to evaluating the effectiveness or our current policy and programs.